

ELEVENTH ANNUAL MEETING

LAND REHABILITATION: Policy, Planning Systems and Operational Programs

June 3 - 6, 1986

University of British Columbia
Vancouver, B.C.



CANADIAN LAND RECLAMATION ASSOCIATION

ASSOCIATION CANADIENNE DE RÉHABILITATION DES SITES DÉGRADÉS

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EDITOR'S NOTE

These proceedings present the conference events in chronological order. Presented papers have been edited for stylistic consistency and re-typed. Time constraints prohibited final text proofreading by individual authors, consequently, the editor accepts responsibility for any errors.

FOREWORD

The British Columbia Chapter of the Canadian Land Reclamation Association was formed in 1985 to provide a local public forum for the exchange of information and experience in land rehabilitation. Comprised of professionals from a wide range of backgrounds and interests, this organization pulled together quickly to host the 1986 Annual Meeting. The diverse membership in the B.C. Chapter was realized in a program that expanded the scope of the conference to include many fields that have not been represented in past programs. The quality of presentations and range of topics kept audience participation at a spirited level. It is our hope that we have initiated a trend to widen the scope of the annual meetings so as to not focus on traditional mining or energy development issues.

I wish to thank all speakers and attendees for making this first formal function of the B.C. Chapter a success. The enthusiastic support of chapter members in the planning and administration of the conference demonstrated a strong desire for a quality meeting. This drive bodes well for the future of our chapter.

A great deal of effort went into the publication of the proceedings of the 1986 Annual Meeting. Care was taken to accurately reproduce all papers, however minor errors may have escaped the review process. We hope that this will not detract from the information presented by the authors.

May the CLRA and all local chapters continue to grow and function as a focal point for land rehabilitation.

KEYNOTE ADDRESS

RECLAMATION - PAST, PRESENT AND FUTURE

J.V. Thirgood

Professor, Faculty of Forestry
University of British Columbia

In this crowded dining room it is difficult to realize the professional isolation of people working in land reclamation even 15 years ago.

It is salutary to recognize that the first reclamation meeting was as late as 1969. This was a short course on the rehabilitation of drastically disturbed land, held at Pennsylvania State University. The intent was to bring together the world's reclamationists. It extended over three weeks and was fully funded by NATO. The organizers searched the world literature and brought together everyone who had written anything on the subject in the previous ten years. They came up with a grand total of 36 names! We were billed by the University as the meeting of disturbed people.

There was bauxite mining in Jamaica; brown coal, atmospheric pollution (this was before acid rain was invented), and regional planning in Germany; pit heaps, open-cast coal and derelict industrial land in the U.K.; strip-mining for coal and phosphate mining in the U.S.; open-pit mining in the Canadian Rockies; the colonization of a new volcanic island off Iceland; and a few other odds and ends. Tin mining in Malaya, the gold dumps of the Witwatersrand, the brown coal of Czechoslovakia and a few old planted coal pit heaps in Belgium were missed. Also, and notably, there were no Australians, for it was not until 1976 that we realized that the extensive Australian literature on sand dune fixation was in fact concerned with the reclamation of mined-out coastal mineral deposits. Such was the state of reclamation as an organized discipline in 1969.

Apart from sizable teams in Appalachia and the American mid-west and in Britain and Germany, most people were working in isolation. Reclamation was largely a concern of a few foresters. Agronomists and ecologists did not really appear on the scene until the change in federal reclamation requirements in the U.S. and the concerns for mine tailings and oil sands in this country.

But land reclamation was by no means a new idea, it has been long accepted in many parts of the world as an integral part of land management. Back in the 1950's I made a survey of some 260 planted pit heaps in England alone. As early as the turn of the century, the Black Country Afforestation Association was already functioning. During 20 years, this voluntary organization, operating on a shoe string, established some 40-odd tree plantations in the English midlands on "tocky" ground and old coal mine, iron foundry, and pottery shard dumps, until it fell victim to the Great Depression. Although many plantations were lost to vandalism when protection was removed, a few of its plantations survive today as memorials to early efforts to make good the ravages of the early industrial revolution. Elsewhere, throughout the European industrial and mining regions, there are sites that had been planted, either as a result of civic concern, as in the Black Country, or in the course of day to day estate management. Particularly in the rural coalfields of northern England, there are scattered small plantations, their industrial origins

forgotten, but identifiable by their configuration, the odd row of old miners' cottages, an old shaft or the foundations of long abandoned buildings. At the Penn State meeting the Germans described a smelter bank that had been planted to trees in the 1890's they were somewhat outcountenanced by a wooded pit heap in England with documentation from the 1840's. Throughout Europe there are quarries, old mine workings, and other once grossly disturbed sites which have merged into the landscape. We have similar situations here in Canada. On our own doorstep there is Queen Elizabeth Park. Not many people who visit this beautiful spot realize that they are looking at an old stone quarry, similarly, the world famous Butchart Gardens near Victoria. In the Kootenays, old mine dumps have revegetated naturally.

Early reclamation efforts were not confined to Europe. Before the end of the 19th century, municipal refuse was being used to reclaim sand dunes at Port Elizabeth in South Africa. Conditions must have been difficult, a major concern was the rotting of the hooves of mules that worked on the site. Today, there is no indication of this tract's original conditions. Successful reclamation is when you do not realize it ever happened.

This morning, one speaker referred to land reclamation by the Romans and the building of medieval towns on garbage dumps. I once lived in the town of Erbil in Northern Iraq which is situated on top of a 300-foot Tell - an artificial mound resulting from the accumulations of 6,500 years of human occupancy - the oldest continuously occupied site in the world. Earlier occupants must have had a first class view of the battle on the plain below when Alexander decisively defeated the Persians, though the Tell surely was not as high then as now.

The bringing of wasteland into productive use has been going on ever since the first stone age man noticed that vegetable waste sprouted on his middens and often produced better food than did adjacent natural soil. The more things change, the more they remain the same. In 1952, I was picking excellent tomatoes on deep mined coal bings in Yorkshire that originated from seed brought up with mine waste from the workings many hundred of feet below ground. They did not have Porta-johns.

Nonetheless, despite this long history of reclamation activity, in the Canada of 1969 such efforts were very few. In eastern Canada, there was concern for mine tailings at Noranda and Timmins, an attempt at tree planting in Cape Breton, and, of course, the bright spot, the work of Tom Peters at Copper Cliff. In the west, there was only a small group of people working in the Crows Nest Pass - like me and a graduate student! We were criticized by a most distinguished dean of graduate studies, a wildlife biologist of world repute, for assisting the mining industry in its desecration of the Rockies. Before turning to UBC, the then Kaiser Coal Company had approached the botany departments of the Alberta universities for advice on the reclamation of their mine and had been turned down flat by each in turn. I had only been at UBC for six months when the Crows Nest controversy erupted, I thought I was unlikely to survive for a

second six months! All this merely because I said that coal wastes could be vegetated. Those were the days when it was an article of faith for many ecologists and foresters that plants required an undisturbed organic layer in which to grow. (It never ceases to amaze me how often intelligent people seem to be unable to use their eyes, or if they do, do not recognize what they are seeing). Just 17 years ago, to be working in mined land reclamation in western Canada was akin to having leprosy - one was expected to ring a bell and cry out "Unclean!" "Unclean!" so that respectable biologists could avoid contamination.

And that was about the total picture of Canadian land reclamation at the beginning of the 1970's. It was certainly a most unlikely place to expect the founding of the world's first land reclamation society.

In reality, the Canadian Land Reclamation Association arose out of a sense of professional isolation. It is also almost certainly unique in that it was in large part founded to provide a vehicle for a professional journal.

For seven years I had been publishing a quarterly international newsletter and bibliography at UBC under the auspices of the International Union of Research Organization. I confess a strong motivation was that in this way, the entire world's output of reclamation reports came across my desk (if anyone wants a complete coverage of reclamation activities, worldwide, for the 1970's, my office has it!). The mailing list increased to about 400 before my dean revolted at the mailing costs. During this time the Ontario Cover Crop Committee, a small study group, was meeting annually at Guelph to discuss land rehabilitation problems and to communicate technical information. Largely formed of seed suppliers, seeding contractors and turf producers, Jack Winch was the driving force behind the group.

We met, and the upshot was the CLRA. At the inaugural meeting there was some disagreement as to whether the new society should be national or international in scope. In the end, the forces of Canadian (or, more correctly, Albertan) nationalism won out, but in typical Canadian fashion, with the compromise that the Association's journal would be international in orientation. (I must confess that I still believe that the decision to maintain a purely Canadian identity was a mistake. The CLRA would have been a significantly stronger organization today, though doubtlessly different in character, if it had cast its net world-wide as the LRA, however, it was not to be).

The CLRA's Reclamation Review was conceived as a professional journal. Unfortunately, it developed early pretensions as a scientific research publication complete with board of review, and there proved to be too few workers in Canada to support it. Eventually, it was hijacked by an ambitious professor from the Dakotas who later moved on to higher things at an eastern ivy league college, and in due course, the journal passed into the hands of Elsevier, the Dutch publishing house, when it was renamed Reclamation and Revegetation Research. Some of our members are on the editorial board. So, although the CLRA was unable to maintain

a journal itself, it did achieve its purpose of seeing the establishment of a well-received international journal dealing with reclamation. Meanwhile, the Association has developed its own professionally oriented newsletter, though the editor still has difficulties in soliciting contributions.

There is a lesson to be derived from this story of the CLRA's venture into publishing. Some academics need to be reminded occasionally that a high proportion of the work of a successful reclamationist, as indeed of any land manager, while firmly founded on an understanding of natural processes, is not based on fully researched scientific orthodoxy. Observation and serendipity have major roles to play, and above all, the successful reclamationist requires the husbandman's instinctive feel for plants and soil.

From the outset the CLRA was envisaged as embracing all aspects of the treatment of drastic disturbances, but we developed early a strong emphasis on mine land rehabilitation. This was unfortunate for it narrowed our vision and we lost a number of members with interests akin to those of the original Ontario Cover Crop Committee. This preoccupation was probably because large-scale open-pit mining was a new development on the Canadian scene, and, as such, attracted attention - people were not used to mining disturbances as they were to poor road construction, raw road cuts, landslides, blocked salmon streams, floods and logged off hillsides, which were accepted as part of the natural order rather than, as all too often, the avoidable consequences of poor management. We also failed to attract a significant international membership to what, because of its title, was seen as a peculiarly Canadian organization.

But if the CLRA was otherwise preoccupied, the public was showing increasing concern for environmental matters - a better term surely is good land management - which brings me to our present meeting. When Paul Ziemkiewicz became President last year, he said he intended to do two things - develop local chapters and extend the scope of the Association. He has succeeded in both his objectives.

At this meeting, through the good efforts of Bill Carr, the CLRA has returned to the original intent of the founding members - a broad-based concern for the restoration and rehabilitation of grossly disturbed environments of all descriptions. Someone said yesterday that reclamation has matured, with that we will all concur. I can recall early reclamation meetings when speakers showed slides of small trial plots of rye grass, fescues and clovers in a moonscape of disturbed land, and were justly proud of their results, and they had every right to be so - they were the pioneers. I myself used to be preoccupied with the need for planning in reclamation - of the need to integrate mined land reclamation with the extractive phase - and went around like a messiah proclaiming the true gospel - today we take all this for granted. We have advanced considerably in our level of understanding and, to a great extent, our early concerns and preoccupations are well on the way to being accomplished.

This meeting is a measure of our success. We have heard from landscape architects about planning railway lines in parks, and rapid transit systems in cities, hydrologists talking about post-logging mass-wasting, stream dynamics and fish, and foresters concerned for the long term productivity that lies at the heart of their profession, and, we have heard about the transformation of municipal refuse and the beneficent use of sewage (surely one of the greatest underutilized resources of our time). Land reclamation is of growing concern, for land managers of all kinds have to satisfy the public concern for the aesthetic values of land while sustaining its productive capacity. Today our efforts extend far beyond turning rock piles green.

In this room are a number of people who have been with the CLRA since its earliest days, but I know they will agree that more important by far are the new faces - there is nothing worse than a professional society dominated by men with gray beards. This has not happened to the CLRA. There has been a steady influx of, what seem to me at least, young people. I do not think I have ever been to a professional meeting before where session chairmen were drawn from graduate students - and an excellent job they did, while, if I may be excused for saying so, the three graduate students from UBC who stepped into the programme gap were products of which any elderly professor can well be proud.

What of the future? What does it hold for reclamation and for the CLRA? The vandals are in retreat from the gates of Rome. Despite present economic conditions, on all sides those with ears to hear can hear expressions of environmental concern and, furthermore, unlike earlier days, these are informed voices. We are seeing a late 20th-century manifestation of the 19th-century North American conservation and forestry movement that transformed American attitudes toward natural resources. Today, as never before, we hear concerns about logging practices, controversies about wilderness preservation, establishment of national and provincial parks, calls for better forestry practices, acid rain, torrent and avalanche control and, in an increasingly technological society, the disposal of hazardous wastes and, most recently, apprehensions about nuclear reactors and the possibility of continent- or even world-wide catastrophe.

The days of the pioneer exploitation of natural resources are coming to an end. Some of us may be impatient at the speed of change - it is the nature of man - but before we can change practices, we must change attitudes of mind. The principles that the CLRA represents will win out. A developed Canada will have a developed programme of environmental maintenance. As we enter into the Age of Sustention, we must ensure that the new environments that will result from the inexorable advance of civilization are both seemly and productive. Certainly, the frontier will be pushed back - we cannot retreat to the nostalgia of the wilderness nor bow down before the Great God Natural Ecosystem, but we do not need to leave a dirty mark wherever we put our hands. Nature is waiting to be turned into a landscape. Canadians will cease to be resource exploiters and become husbandmen, even if working on a scale unimagined by earlier generations.

A few weeks ago, I read an exam script in which the student had written "to restore productivity to deserts it is necessary to irritate them". Only when the Canadian people are sufficiently irritated by such scenes of man-made catastrophe, as we have been shown at this meeting, will they, in turn, so irritate the wheelers and shakers of our society that environmental maintenance, and with it the purpose of this Association, will be adequately addressed. And this will be sooner than we think.

RECLAMATION PROJECTS SPONSORED BY THE CANADA

- B.C. MINERAL DEVELOPMENT AGREEMENT

D.M. Galbraith, P. Eng.

Mine Reclamation Inspector

B.C. Ministry of Energy, Mines and Petroleum Resources

On July 30, 1985, a 5 year \$10,000,000 agreement was signed in Prince George between Canada's Minister of State for Mines, the Minister of Energy, Mines and Petroleum Resources, and the Minister of Industry and Small Business. The object of the joint agreement was to stimulate development of the provinces mining industry. One item included within that agreement was in the amount of \$18,000 to fund year one of a proposed 3 year study of mine waste dump resloping. The project was described in the application for funding as follows:

"Dump faces constitute a significant portion of the approx. 25,000 hectares of land disturbed by mining in B.C. The cost of resloping waste dump faces is factorially higher than other reclamation costs. The Technical and Research Committee on Reclamation - an ad hoc industry, government and university committee - has made this issue the No. 1 research priority. A consultant study is recommended to search literature, interview individuals, examine sites, analyze findings and present a report at the annual B.C. Mine Reclamation Symposium. The Technical and Research Committee will assist in review of results, and corporate members of the committee will dedicate project work to it in the field."

The MDA management committee approved this request and proposals were subsequently solicited from consultants for undertaking the work at a set fee of \$18,000, plus an extra \$1,000 which was donated from the Technical and Research Committee's sinking fund.

A contract was subsequently let to Norecol Environmental Consultants who, in conjunction with Thurber Consultants Ltd. undertook literature reviews, interviews and analysis and submitted a report entitled, "Mine Waste Dump Management (Resloping) Study, May 1986".

The report proposed three groups of criteria to be used in determining the need for and extent of resloping required:

GROUP 1: Those that are important at all mines:

- 1) Cost
- 2) End land use

GROUP 2: Those that are important in certain circumstances:

- 1) Safety
- 2) Sediment production
- 3) Acid mine drainage and production of toxins

GROUP 3: Those of secondary importance:

- 1) Ease of revegetation
- 2) Substrate considerations
- 3) Appearance

Committee members have not had sufficient time to fully review and comment on this report so it will be kept confidential to the committee and the MDA management group until released.

A proposal covering year 2 of the study is under preparation and will soon be submitted to the MDA management group.

A second project was recently approved for funding by the MDA in the amount of \$10,000. This one is designed to evaluate the state-of-the-art of flow-through rock drains. The project was described in the application for funding as follows:

"Mining in B.C. requires waste rock to be dumped into valleys. When streamcourses are encountered, these must either be relocated, or dumping directed to a more remote location. Both options are costly and each will have its advantages environmentally. A technique recently tried on a few sites involves the placement of a blanket of large rock over the streamcourse on top of which the overburden dump is constructed. The result is a flow-through rock drain. Questions are however posed as to the limiting factors in design and construction (stream flow maximum, bedload, foundation, etc.) and function over geological time. These must all currently be answered on a case-by-case basis. An initial symposium of experts from around the world is proposed, to document the state-of-the-art with a follow-up two year study program to develop design and construction criteria."

Further support for the symposium has been provided by the Coal Association of Canada, Ministry of Environment, Mining Association of B.C., and Crows Nest Branch CIM. The symposium will be held this September 8th to 11th at the Inn of the South, Cranbrook, B.C. and will feature a two day field trip September 8th and 9th of the Kootenay coal mines (and a cook-out) and two days of talks at Cranbrook. All for the amazingly low price of \$150. It is hoped to have sufficient surplus to fund a follow-up study.

MDA funding has proven to be a valuable aid in attempting to resolve what has been a long-standing debate (with respect to re-sloping), and a vital assist in the attempt to prove out a promising development technique. The Technical and Research Committee looks forward to further progress courtesy of the Canada-B.C. mineral development subagreement.

PLANNING FOR THE FRASER-THOMPSON CORRIDOR -
A CLASH OF PERSPECTIVES

Andrew R. Thompson

Professor of Law
Director, Westwater Research Centre, U.B.C.

INTRODUCTION: THE TWIN-TRACKING DISPUTE

This is a chronical - a story of personal impressions and reactions to the twin-tracking dispute in the spring and summer of 1985. My role at that time was as a "facilitator" appointed by the federal Minister of Transport to attempt to find means of reconciling the differences between CN Rail and the Alliance of Tribal Nations.

I need say little about the twin-tracking project itself, for it is described in the paper by Paul Scott. But I'll remind you that the government of Prime Minister Trudeau had given the project an imprimatur of national interest, decreeing by cabinet order that the twin-tracking should proceed. Thereafter, the project became a management problem for CN Rail and government agencies. This was the first stage of government response to the twin-tracking project.

THE FIRST STAGE

Historically, railways would proceed with construction of a rail line as masters of their own destiny brooking no opposition to their progress. But this was 1979. There were cautionary voices and rising concerns about construction impacts in the canyons and valleys of the Thompson and Fraser Rivers.

Obviously the project fell within the EARP program for screening federal projects having significant environmental impacts. So it was agreed that while the twin-tracking project would go ahead, there would be environmental and social impact review under the mandate of the Federal Environmental Assessment Review Offices (FEARO). Mr. Scott has explained the initiation and conduct of this review. Its purpose was to define impacts and to contribute to CN Rail's planning for their avoidance and mitigation.

Meanwhile, the federal and provincial governments had marshalled their regulatory forces. First, for construction planning, a Steering Committee (SC) had been established to oversee the assessment of environmental impacts and their implementation of design changes that would avoid or mitigate them. Next, a Technical Working Group (TWG) had been formed under the umbrella of the SC to provide expertise of a scientific and technical nature to this design review process. It was this process that would receive and implement the recommendations of an environmental impact nature that would emerge from the EARP panel review.

Let me define the characteristics of these first stage regulatory mechanisms as I perceived them to be.

The Design Review Process

CN Rail contended that it had autonomous power to design and

construct the second track without submitting to any regulatory authority, either federal or provincial, other than the federal Railway Act, and the Canadian Transport Commission (CTC).

However, CN Rail was prepared to cooperate with federal and provincial environmental authorities and take part on a voluntary basis in the EARP process. In particular this cooperation would require a close working relationship with the federal Department of Fisheries and Oceans (DFO) which has responsibility for protecting the famous salmon runs of the Fraser and Thompson Rivers. Moreover, the CTC had decided to link its statutory approvals of construction to the Design Review Process by requiring CN Rail to file construction plans which incorporated the results of the design review.

To discharge its function of overseeing the design review, the SC was comprised of a senior representative of DFO of the federal Department of Environment (DOE) and of the provincial Ministry of Environment (MOE). As well, CN Rail was represented by a senior official. The committee was chaired by the representative of DOE.

Characteristics of this Steering Committee was that it had no formal status. There was no statutory mandate - there were not even written terms of reference in any official sense. The assumption was that the TWG would reach consensus decisions about environmental impacts and that these decisions would be acceptable to CN Rail and the government agencies. CN Rail would then implement them through design changes. Should consensus be lacking, there would be reference to the Steering Committee to decide on an appropriate course of action to resolve the difficulty, but the Steering Committee was not in any sense an appeal body. It could not make decisions binding on CN Rail.

In the end, CN Rail had the final say about what changes would be incorporated into the design plans. It had only to satisfy the CTC that it had consulted with the government agencies through the Design Review Process.

Underlying this assumption about cooperation were certain fundamental issues and contentions that could not be assumed away. Federally, while DFO would cooperate in the process of design review, it could not surrender its powers under the Fisheries Act to protect fish habitat from construction impacts, and to use criminal prosecution of CN Rail as a means of enforcement, if that were necessary. Moreover, the mandate of DFO was to protect the fish and their habitat - not to protect the rights or interests of fishermen, be they native Indians or non-Indians.

Provincially, there was a basic dilemma. Under the B.C. Water Act, water resources are declared to be the property of the Province. Under the B.C. Land Act, the beds of lakes, rivers and streams are declared to be provincially-owned. Private interests in water or in the beds of lakes, rivers or streams can be acquired, but only by the issue of a provincial water licence or a provincial land grant. MOE had tried to persuade CN Rail to apply for water licences with respect to interferences with the Fraser

and Thompson Rivers caused by the twin-tracking project, but CN Rail had refused, claiming that it already had all the land and water rights it needed by virtue of its railway rights-of-way and the provision of the federal Railway Act. Were the province to have pressed its claim, it would have been necessary to confront Ottawa with basic jurisdictional issues respecting federal and provincial powers and responsibilities. The province chose not to do so, contenting itself with the consultative role offered by participation in the SC and the TWG.

That CN Rail was in the driver's seat was exemplified by the fact that the chairman of the TWG was CN Rail's own consultant.

Summing-up

To sum up, the government's regulatory mechanism for the twin-tracking project:

- was based on an assumption of consensus decisions;
- put aside basic jurisdictional and mandate issues; and
- placed CN Rail firmly in charge of impact assessment and management.

The EARP Panel

With an increasing, if unfocussed expression of public concerns over the impacts of railway construction in the Fraser/Thompson corridor, the EARP panel was intended to provide a means for these concerns to be publicly voiced. There was no question about the project going ahead - that decision had already been made by the federal cabinet. But it was assumed that the recommendations which the EARP panel could make to lessen impacts would be implemented through the Design Review Process and that this response would satisfy public concerns.

It soon became apparent that there was gross miscalculation. The concerns which dominated the panel's public hearings could not be answered by referring them to mere technical review by government and railway specialists. The issues focussed almost entirely on the salmon resource. Over 80% of the official transcripts dealt with submissions on behalf of Indian bands owning reserves along the rivers. Their measures being considered for salmon by DFO. In particular, they questioned what DFO's "no net loss" policy could mean, and their concerns were only heightened by learning that the "no net loss" policy would be implemented on a "river system basis". As the understanding of this qualification emerged (it meant that a loss of fish or habitat at point A on the Fraser/Thompson Rivers could be offset by an enhancement project at any other point on this vast system), it became apparent that the protection DFO offered was protection of the salmon resource and its habitat in a general sense, but not protection of the fishing rights of the Indians.

Moreover, when CN Rail obtained TWG and SC approval of its design plan for the critical 10-mile Ashcroft section of the Thompson River after the EARP panel had completed its hearings but before its report and recommendations had been made, the Indians

concluded that the EARP process was without substance so far as their interests were concerned.

Summing-up

The contribution of the EARP process to the twin-tracking dispute can be summed-up as follows:

- it heightened the knowledge and awareness of the Indian people of the Fraser/Thompson Rivers concerning impacts on the salmon resource and what government agencies might do about them;
- it politicized the Indians, enabling the formation of a new Alliance of Tribal Councils motivated by their common river corridor concerns;
- it made apparent the dominant role of CN Rail in the government regulatory processess for design review;
- it revealed the weakness of the EARP panel in that its report and recommendations would come too late to be effective.

The imminent construction of the Ashcroft section in the Thompson River was the event that brought Indian cooperation with the EARP process to an end. They then turned their efforts to political and legal action, initiating a second stage of government response to the twin-tracking project.

THE SECOND STAGE

The Indians Intervene

The complaint of the Alliance was that the placing of rip rap on the bed and banks of the river to construct the second track would both interfere with fish and their habitat and impede Indian methods of fishing. They claimed legal rights both to the bed and banks of the river and to the right to fish in customary ways at established places along the river, basing these claims on their Indian reserves. For example, the documents which had created the Oregon Jack Reserve in the 10 mile Ashcroft section of the river included language expressly giving the band members the right to fish on both sides of the Thompson River for a distance of two miles downstream from the mouth of Oregon Jack Creek. They also asserted aboriginal rights to fish.

When it appeared that construction would begin in January, 1985, this band and others commenced an action in the Supreme Court of British Columbia for an injunction against CN Rail preventing it from proceeding with construction until Indian rights were determined or Indian agreement was reached.

The Alliance then took their case to Ottawa, appearing before the Standing Committee of the House of Commons on Indian Affairs, Fisheries and Forests to ask for a year's delay of the twin-tracking project. This intervention succeeded in getting the Minister of Transport, with the support of the Minister of Indian Affairs and Northern Development, the Minister of Fisheries and Oceans and the Minister of Environment, to send a letter to Dr.

J.M. Le Clair, President of CN Rail requesting that a process be established "to allow the (twin-tracking) program to go ahead subject to the concerns of the Indian people being met, specifically that they be directly involved in the decision process relating to project construction". Attached to the letter was a Statement of Requirements. For the Ashcroft section, it asked CN Rail to "examine specific design options" and "to incorporate design changes wherever possible to mitigate Indian peoples' concerns with specific heritage sites, fishing sites and access trails." In general, it called for Indian representatives on the SC and the TWG, implementation of SC and TWG recommendations by CN Rail, and arbitration if the parties could not agree. It recommended that the parties choose a facilitator to assist them in resolving their differences. That is the role to which I was appointed by Transport Minister Mazankowski with the agreement of CN Rail and the Alliance.

Intense negotiations, spurred on by court appearances and confrontations between Indians and rock-dumping trains, failed to resolve issues over the following six months. The parties had agreed to clear about one-third of the 10 mile section for construction when the spring run-off brought a halt to operations. There remained basic differences over the scope of the overall design review and the options which CN Rail would be obliged to consider for the remaining portions of the Ashcroft section.

The Court Decides

The Indians pressed their court case forward. On August 19, 1985, Mr. Justice Macdonald issued an interim injunction restraining CN Rail from proceeding with further work on the Ashcroft section pending a full trial of the Indians' claims to ownership of the banks and bed of the river and of the right to fish. This trial is now scheduled for the spring of 1987. Meantime, no twin-tracking construction work is proceeding in any section of the Thompson and Fraser Rivers downstream from Ashcroft. (On October 21, 1986, it was announced that CN Rail has shelved its twin-tracking project indefinitely.)

A Difference in Perceptions

What stood between the parties and an agreement was their different perceptions about their rights and responsibilities. CN Rail perceived its project to be in the national interest, with a full legal mandate to proceed with construction according to efficient economic and engineering standards. It would meet environmental impact design requirements within reason, and it recognized a responsibility, specially endorsed by the federal cabinet ministers, to try to accommodate Indian concerns, but it acknowledged no legal rights on the part of the Indians, and would not agree to design changes requested by the Indians if these changes would result in substantially increased costs. For example, it would not agree to side cuts into the mountains to enable the second track to be located on the up side of the existing main line because these side cuts would cost in the order of ten times the costs of dumping rip rap into the river.

Alliance members believed fundamentally in their ownership of the bed and banks of the river and of the right to fish at customary times and places. They owed it to future generations of Indians to preserve the rights which their fisheries and engineering consultants said were threatened if the second track was to be built by filling in the river bank. They also had in mind that CP Rail would be twin-tracking its mainline on the other bank of the rivers, and that highway straightening and widening, pipelines and transmission lines would place future demands on the corridor.

In their minds, it was CN Rail that was proceeding illegally, for CN Rail had not followed the procedures laid down in the Indian Act for expropriating Indian lands.

Meantime, the SC and the TWG, complying with the ministerial requests, had invited Indian representatives to join their ranks, and Indians began to participate in the design review process on other sections of the corridor with the assistance of their fisheries and engineering consultants. This process might ultimately have proved of benefit in resolving differences between CN Rail and the Alliance. But, basically, the functioning of the SC and the TWG has been of only peripheral relevance during this period of time when mediation efforts and court proceedings have dominated the stage.

Summing-up

Summing up this second stage, the following points can be made:

- the first stage efforts - the Design Review Process and the EARP panel - proved to be totally incapable of dealing with the issues between CN Rail and the Indians;
- forceful political intervention created a situation in which the parties extended their efforts to reach a compromise as far as possible;
- the perceptions of the parties' legal rights were so totally different that compromise was not possible;
- submission of the issues to the Court brought the regulatory process to a virtual standstill; and
- the parties now expect that the court's decision will decisively shape the ultimate outcome - either allowing CN Rail to proceed or requiring CN Rail to meet the Indian's terms and conditions.

THE THIRD STAGE

The Indian Vision of the Future

There are two visions of the future. If the Alliance wins its court case, with a legal affirmation of its ownership of the banks and beds of the rivers and of the right to fish where their 70 - odd reserves abut the Thompson and Fraser Rivers, CN Rail will have either to reach agreement on the terms and conditions that are acceptable to the Indians or initiate expropriation proceedings. Under s.35 of the Indian Act, such expropriation

requires federal cabinet approval, elevating decision-making to the highest political level. If expropriation is authorized, the process requires that Indian interests be recognized so far as possible, with compensation in money only as a last resort. Certainly, CN Rail would have to come "cap in hand" to the Indians.

Other developers would, of course, be affected in the same way as CN Rail. In some cases the alternative of expropriation would not even be available - provincially granted expropriation powers cannot be enforced against Indian reserve lands.

Now that the bands and tribal councils of the corridor have come together to form an Alliance, there is potential for an integrated development planning process implemented by the enactment of 70 complementary reserve by-laws. Taken together, these by-laws could effectively control corridor developments, establishing a joint planning council, requiring the submission of development plans, conducting public hearings and developing principles and criteria for approving or modifying development proposals. This corridor planning and decision-making process could operate cooperatively with the regulatory mechanisms of the federal and provincial governments or independently of them. Conjoined with the fisheries management by-laws of the type recently approved by the Minister of Indian Affairs and Northern Development for the Indian bands of the Skeena River, such development planning and approval by-laws could go a long way toward realizing the kind of future for the Fraser/Thompson corridor that the Indians envisage.

Governments' Vision of the Future

Seldom are alternatives presented so clearly as in this twin-tracking dispute. Alongside this very explicit Indian view of the future, we have the reasoned conclusions of the Fraser-Thompson Corridor Review outlining a government vision of the future.

This government vision is basically an extension of the regulatory mechanisms utilized in the first stage of the twin-tracking project. That is, to quote the Review, "The Panel advocates building upon existing environmental management authority or increasing responsibilities for particular agencies". A "two-tiered" system is advocated - an Executive Committee as an overseer (substitute "Steering Committee"), and a Corridor Management Committee as a planner and coordinator (substitute "Technical Working Group". The essential elements are:

- no alteration of existing mandates of federal and provincial agencies;
- no attempt to identify and resolve basic conflicts among the parties; and
- reliance on "coordination" and "cooperation" as the catalysts for sound corridor management.

It's not unfair to label this vision of the future as the bureaucrats' ideal. British Columbians will recognize its progenitor in the Fraser River Estuary Management Program (FREMP)

recently initiated as the product of a 10-year study of the problems of the Fraser River Estuary. Its essence is coordination and cooperation, and no interference with the existing bureaucratic mandates.

What seems remarkable to me is that, while the Fraser-Thompson Corridor Review gives substantial attention to Indian food fishing (page 11) and to the impact of corridor developments on Indian reserves (page 20), it nowhere acknowledges the existence of the twin-tracking dispute between CN Rail and the Alliance or the court proceedings that may have so decisive an effect on corridor management.

It's as if there were one world for bureaucrats and another world for those who have interests that will be affected by corridor developments.

That's not necessarily an unusual dichotomy. Government agencies exist to serve the interests of citizens, including those whose interests are directly affected. If dissatisfied, the public can resort to the political process. Additionally, the Fraser-Thompson Corridor Review recommends that "transportation developers, Indian organizations, public groups and local representatives" be included in the Corridor Management Committee. Therefore, this government regulatory program can be held forth as representing the universe of environmental management, though proceeding with little regard for the world of private interests and conflicts that surrounds it. Central to this paradigm is the idea that coordination and cooperation can solve all management problems. It is the rational-scientific model of governance. "Coordination" requires that all necessary data and information be made available to all responsible and affected parts in a usable and timely fashion and that all such parties have full opportunity to document and record their interests and the positions they take with respect to them. "Cooperation" assumes that all such parties will then be governed by principles of fairness and reason to reach consensus decisions on the issues dividing them. Such consensus will include a just recognition of individual rights and entitlements that are afforded by the legal system.

For all its assumptions and conceits, it is this rational model we must live by, having rejected naked power, divine revelation and authority without reason. But an increasing understanding of the workings of this rational-scientific model is leading us to an equally increasing awareness of its limitations and constraints.

A principal example of these limitations and constraints lies in the matter of "rights". Individually and collectively we have perceptions about our "rights". To the extent possible we seek to have these expressed in our formal laws, and even constitutionally entrenched so that they will not lie in peril of change. We expect these rights to be honoured in our governing system. Neither reason nor fairness is a substitute for recognition of these rights. When rights clash we expect "justice" - that is, a sanctioned system of adjudicating and pronouncing how the clash is to be resolved.

The bureaucratic model of government assumes that the "rights" of rational people can always be satisfied through coordination and cooperation resulting in consensus decision of government. Fortunately, this result is usually true. But it is also true that in many cases people's perceptions of "rights" cannot be so readily accommodated. When these perceptions are ignored or suppressed, they are more likely to fester than to be forsaken. The consequences may be political lobbying, court actions or even defiances of the law. We know all of these reactions in Canada. Sometimes, they lead to change. In other cases they are stored to be retrieved as a legacy of bitterness and conflict in the future.

The question I ask is whether the bureaucratic model of governance should ignore this "irrational" force for change. Is it always better to mask conflict under the cover of coordination and cooperation? Would environmental management in the Fraser-Thompson corridor be enhanced by coming to grips with the dispute between the British Columbia government and CN Rail over who controls the water resources of the rivers? Would it be more in tune with the future were governments to recognize that Indians are claiming legal rights to the banks and beds of the rivers and the right to fish such that, if these rights are affirmed by the courts, Indians must be afforded a major role in environmental management of the corridor?

My own belief is that we lose ground when we fail to confront wide differences of perceptions about basic rights. Coordination and cooperation cannot always carry the day. In the twin-tracking case negotiations merely revealed how far the parties are apart. In my view, it was a fitting service to the rational-scientific model of governance to submit the basic question of entitlement between CN Rail and the Alliance of Tribal Councils to the courts. When the courts have decided, it will then be possible to design an abiding system of environmental management for the corridor - not before!

REHABILITATION - ITS MANY FACETS AT ONTARIO HYDRO

A.S. Ansell

Section Head - Environmental Specialties
Ontario Hydro

ABSTRACT

The term facets has many definitions as does the term rehabilitation. When these terms are linked with the issues identified by members of this Association in the survey taken in 1985, the spectrum becomes very broad. These issues, or facets, range from toxic waste sites to land use planning to ecosystem renewal. In all cases, they depict various concerns and point out the need for subsequent activities for the reclamation, rehabilitation and restoration of our environment. Industries and governments are not exempt from these issues and activities, most of which are regulated by environmental legislation. At Ontario Hydro, it is not a case of what to do, but more one of how to do it to comply with environmental requirements. In order to undertake any project, some research is required. Sometimes this means breaking new ground, such as in reclamation to establish vegetation on fly ash or on spoil piles excavated from new generating station sites. Abandoned gravel pits on rights-of-way must be rehabilitated through revegetation and sometimes landscaping to assist in protecting the security of the lines. The greatest activity, however, is in the area of restoration. Restoration is required because of Ontario Hydro's land based activities in forested and agricultural lands and as a result of natural occurrences. Through the interaction of water with the components of the landscape unit, Nature herself, or Ontario Hydro operational activities, many erosion problems must be dealt with and corrected. Other land based restoration problems stem from various sources, and involve many different stages. These may be pipelines utilizing right-of-way lands, adjacent subdivisions and their drainage problems, construction, and acts of nature. Each has its own unique solution, and each is one of the facets of rehabilitation undertaken by Ontario Hydro and other utilities across Canada.

INTRODUCTION

The term facet has many definitions. It can mean outside, exterior, surface, skin, or facade. However, the best-known definition is: "one of the small polished surfaces of a cut gem". The various aspects of our own work programs and the areas covered by the program at this annual meeting are facets of the major gem: "rehabilitation".

Rehabilitation, reclamation and restoration are sometimes used interchangeably, but each has its own distinct definition. Reclamation means to claim back, or to make capable of being cultivated or lived on. Restoration is defined as a putting or bringing back into a former, normal, or unimpaired state or condition. Finally, rehabilitation means to restore, to put back in good condition, or to re-establish on a firm, sound basis.

When the facets of rehabilitation are linked with the issues identified by members of this Association in the survey taken in 1985, the spectrum becomes very broad. Some examples of these issues, in descending order of priority, include toxic waste sites, cost effectiveness, reclamation after abandonment, regulation and legislation, land use planning, public awareness, reclamation performance, political trade-offs, high technology, and so on.

Industries and government are not exempt from these issues and activities, most of which are regulated by environmental legislation. At Ontario Hydro, the environment is defined as the natural system of land, air, water, plants, and animals, including man and his interaction with the system. Because of this interaction, it is not a question of what to do, but how to do it in compliance with environmental requirements.

RECLAMATION

In order to undertake any project, research is required, and sometimes this means breaking new ground, such as trying to establish vegetation on fly ash at our Nanticoke Generating Station. In this reclamation project, the initial seeding yielded very poor results because of the different consistencies of ash, which ranged from very coarse to very fine. Grasses simply died; legumes also died, but held on for a longer period of time. Greenhouse testing using soil additives and many different species of grass was used to find out what should be done. The best results were shown on the coarse ash.

Another reclamation project occurred at the Darlington Nuclear Generating Station. The station site was excavated down to bedrock for stability purposes. The resulting spoil pile covers approximately 37 hectares (90 acres), is 45 meters high (150 feet), and contains 15 million cubic meters (20 million cubic yards) of excavated material. A testing program was established to determine the best vegetation mix for the site, with the result that, two years later, vegetation is established on the slopes of the pile.

REHABILITATION

In the area of rehabilitation, gravel pits are always a problem. When the Niagara escarpment was crossed by a 500 kV transmission line, Ontario Hydro made a commitment to rehabilitate the site. Treatment of the site included regrading, hydroseeding, and planting of trees along the road and hawthorne on the upper slopes. Hawthorne was used because a local farmer leasing the land wanted to graze sheep on the property and it was felt hawthorne would keep the sheep off the upper slopes. Unfortunately, the farmer never did graze sheep on the property.

At the Colwell pits just south of the Essa Transformer Station, rehabilitation was also necessary. Red pine was planted over 10 years ago and did very poorly because of sandy and very dry site conditions. Some jack pine which was accidentally mixed with the red pine planting did extremely well. This suggests that the proper plant material must be selected to meet specific growing conditions. Carolina poplar and black locust have recently been planted on the site.

RESTORATION

A great amount of time is spent on restoration at Ontario Hydro because of land-based activities on forested and agricultural lands and because of natural occurrences. To minimize the disturbance to the environment, forest areas are selectively cut. In areas of soils with a high potential for both wind and water erosion, windbreaks are sometimes left to protect the soil and encourage the establishment of cover crops. This was done during the construction of a new 500 kV line through the Northumberland County Forest. When the cover crops are well established, the windbreaks will be removed, as they will eventually be incompatible with transmission lines.

Areas requiring vegetative cover are handled in different ways. Rights-of-way in the north are seeded from the air by fixed-wing aircraft, as helicopters are too expensive. Seeding is often done in southern Ontario from a spreader drawn by a snowmobile and, for small areas, the hand-held cyclone seeder is used. The ultimate results are good catches of reed canary grass and champ timothy in the north, and crown vetch, creeping red fescue, tall fescue, clover, and other plant materials in the south. In both situations, cover is established not only to protect the environment, but also to provide competition for unwanted woody vegetation which could grow into the lines.

Immediately after construction, areas of rights-of-way must be restored. The areas around tower bases are graded and hydroseeded. In specific instances, fabric materials are installed to help stabilize slopes and prevent erosion while vegetative cover is being established. Once construction has been completed, access roads across agricultural lands must be removed. The stone and filter fabric under the stone are lifted, the area is chisel-plowed and, finally, rotovated in preparation for seeding. In some instances where major drainage ditches are involved, interlocking brick has been used to protect the tower

footings. Installations in this kind of situation are generally designed to withstand a one-in-a-hundred-year flood.

Other land-based restoration problems stem from various sources and involve many different stages. Pipelines use rights-of-way and can cause problems, especially at stream crossings. The Interprovincial Pipelines crossing of the Oakville Creek offered potential for serious erosion, which could threaten not only the watercourse but the pipeline and the security of the towers on the right-of-way. The finished product involved gabions for toe protection, rip rap, subsurface breakers, and vegetative cover.

The York Durham sewer is another example of secondary use of a right-of-way. The installation of the "big pipe", as it is affectionately called, required special precautions to be taken to protect wetland areas, but even then silt still bypassed the berms and straw. After installation of the sewer, the area was regraded in preparation for seeding.

Subdivision adjacent to rights-of-way are another type of problem. Various soil conditions, ranging from wet organics to sand, create drainage difficulties. Even though what seem to be appropriate protective measures are taken, such as the installation of sandbag groynes and gabion mats, they sometimes fail and have to be redone in a more elaborate manner. This includes the installation of catchment basins, rip rap, and sod. Once again, a combination of methods is used to correct a specific problem.

Because of water interacting with components of the landscape unit, nature herself, or Ontario Hydro operational activities, many erosion problems need to be dealt with and corrected. The Mississagi River required bank protection because of water level fluctuations caused by Ontario Hydro in its operation of the Red Rock Falls generating station. Approval was received in 1982 from government agencies to proceed with remedial action. Stabilization of the banks just above the water level was achieved by means of rip rap, which was dumped on an access road and placed in position by means of a gradall. Testing of plant materials, which included both shrubs such as alder, willow, and red osier dogwood, and grasses, was undertaken to determine which was most suitable for the location. The final product was a combination of rip rap and vegetation which extended for approximately 18 kilometers, used 240,000 tonnes of material, and to date has cost over six million dollars.

Riverbank erosion can cause considerable concern for the security of a tower line, as evidenced by the erosion taking place on the Saugeen River. Gabions were used extensively at two locations from the toe up the bank to overcome this problem. Extra reinforcement had to be installed at one curve to prevent the ice from ramming the tower legs and causing damage to the towers. Rip rap and vegetative material was used to complete the project.

At one of our transformer stations in Toronto, Balfour

Junction, erosion problems affecting underground cables were related to station drainage and drainage of the surrounding area. Because of the steepness of the slope, and the attitude of local ratepayers, much of the work had to be done by hand. Once the cables were exposed, new K-Crete was used to cover the oil-filled cables, as the old K-Crete had shifted because of subsurface erosion. In the channel around the cables, filter fabrics, drainage pipe, and subsurface headers had to be installed to ensure water drained away to prevent further erosion.

On the East-West line at the Magpie River crossing, erosion problems threatened the security of the line. The slope was regraded, seeded, and a fabric material installed. The success of the solution is indicated by the new growth coming through the fabric.

Acts of nature, although brief, can be quite devastating. Massive transmission towers can be toppled and crumpled like pretzels, as happened during a tornado in southern Ontario in 1985. The immediate task, of course, was to get those lines back in service, with restoration taking place once the necessary repairs had been made. Lands under temporary access roads had to be restored, and sensitive areas required appropriate treatment to overcome the six-foot-deep ruts.

Through all of the work of reclamation, rehabilitation, and/or restoration, it must be remembered there are three specific stages - research, implementation, and maintenance and monitoring. Each problem has its own unique solution, each is one of the facets of rehabilitation undertaken by Ontario Hydro and other utilities across Canada, and each involves these three specific stages. By taking appropriate steps necessitated by man's interaction with the natural environment, we can avoid the lingering aftermath of nature's ravages and look forward to tranquility and the assurance that our lights will remain on.

LAND REHABILITATION - POLICY AND PROCEDURES AT TWO
HYDROELECTRIC DEVELOPMENTS IN NEWFOUNDLAND

G. Paul Rideout

Dept. of Environment
St. John's, Newfoundland

ABSTRACT

In 1975 Newfoundland and Labrador Hydro (Hydro), a provincial crown corporation, announced plans to develop the hydroelectric potential of the Upper Salmon and Cat Arm areas to meet a forecast provincial energy deficit in 1983. As part of Newfoundland's environmental assessment process baseline studies were carried out from 1975 to 1980 to evaluate the environmental acceptability of the proposed developments. The resulting Environmental Impact Statements for the respective developments were submitted by Hydro in 1980 to the Minister of Environment. Included in both impact statements was a commitment by Hydro to rehabilitate disturbed land areas.

Construction of both projects began in 1980 and was completed for the Upper Salmon and Cat Arm areas, in 1983 and 1984 respectively. Associated with the construction of these hydroelectric developments was a network of access roads, dams, dykes, borrow pits, rock quarries, spoil areas, waste disposal sites, campsites, marshalling areas and transmission lines. At both sites, rehabilitation is still ongoing by Hydro, in consultation with the Department of Environment.

The degree of disturbance and the problems associated with rehabilitation of these hydroelectric developments have been varied. The soils at Cat Arm are generally shallow, coarse-textured and nutrient-poor, reflecting the resistant nature of the bedrock underlying most of the area. These soils and the severe climate of the area impose restrictions on plant growth, and therefore on rehabilitation. The Upper Salmon area receives intensive use by caribou of the Grey River Herd (population 5000 animals). The area is used for calving and the post-calving aggregation and is a major migration route used during both spring and fall. This fact has influenced rehabilitation strategies.

Where reclamation has been undertaken the desired result has been prevention of erosion so that topsoil remains in place to promote a return of native species. Work has involved respreading of salvaged overburden and topsoil, grass-seeding and planting of native tree species.

At present the Environmental Assessment process plays an important role in land reclamation. Existing rehabilitation legislation is inadequate and government is in the process of drafting regulations to deal with this issue.

INTRODUCTION

In 1975 Newfoundland and Labrador Hydro (Hydro), a provincial crown corporation, announced plans to develop the hydroelectric potential of two major watersheds in insular Newfoundland, the West and North Salmon Rivers (Upper Salmon) located in south-central Newfoundland and the Cat Arm River on the upland plateau of the Great Northern Peninsula. At that time the Environmental Assessment process in Newfoundland was being developed and, in anticipation of forth coming regulatory requirements, the provincial government required Hydro to carry out comprehensive studies to evaluate the environmental acceptability of the proposed developments.

Environmental Impact Statements (EIS) were prepared for each proposed development and were submitted by Hydro to the Newfoundland Minister of Environment in 1980. Both impact statements included commitments by Hydro to rehabilitate disturbed land areas (Newfoundland and Labrador Hydro, 1980a;b).

The Upper Salmon area is used extensively by caribou during their annual migrations and is the site of the post-calving aggregation in mid-summer. In addition to extensive use at these times, small numbers of caribou can be found in the area during the rest of the year. A desire to protect this valuable resource played a large part in decisions to actively rehabilitate disturbed areas.

At the Cat Arm site caribou use is minimal. Still it was recognized that to protect remaining watersheds; (some of them prime Atlantic salmon habitat) and to encourage a return of other wildlife, areas prone to erosion would have to be rehabilitated.

At both sites a desire to restore and preserve the beauty of the natural landscape was also a factor in decisions to rehabilitate.

In the past, programs aimed at rehabilitating disturbed areas in Newfoundland have been few. Resource developments such as mining and hydroelectricity have proceeded with little thought given to the eventual reclamation of land exploited so that a single resource could be developed. Today, however, governments and industry are implementing procedures directed at ensuring that disturbed lands are reclaimed and allowed to regain varying degrees of productivity. Why should land impacted by the development of one resource be lost to all other potential uses?

Construction at both developments began in 1980. Associated with the construction of these hydroelectric developments, both located in remote relatively undisturbed areas, was an extensive network of access roads, dams and dykes, borrow pits, rock quarries, spoil areas, waste disposal sites, construction camps and transmission lines. Damming of the two rivers resulted in the flooding of a total of 8000 ha of shoreline. This loss of land is accepted by most as being an unavoidable cost of producing hydroelectric power. Many disturbed areas outside the flood zone

were to undergo rehabilitation.

OBJECTIVES AND CONSTRAINTS

The primary objective of rehabilitation was to control erosion so that organics and topsoil would remain in place to promote a return of native flora. Experiences at other resource developments had demonstrated that in the absence of a vegetative cover serious and expensive erosion problems were often the result (Newfoundland and Labrador Hydro, 1984). Uncontrolled, this erosion precludes other resource use on that land, threatens adjacent habitats and creates aesthetically unacceptable conditions.

The preservation of organics and topsoils for future resspreading was a condition required of Hydro prior to Government approving either project. Individual construction permits such as stream crossing approvals and quarry/borrow area permits contained conditions binding contractors to practices that would help ensure successful reclamation. These regulated procedures combined with Hydro's own commitments in the EIS, have resulted in the province's first major resource developments where eventual reclamation has been a planning and procedural objective. We are still assessing the success of these efforts. Reclamation work is continuing in 1986 at both sites.

The soils of Newfoundland are generally acidic, often very shallow and frequently of low nutrient content. These factors, combined with a relatively short growing season can have a major impact on the potential for rapid natural revegetation. Soils subjected to grubbing, stripping and long-term stockpiling with resultant nutrient leaching are of diminished fertility when respread. In addition, there is often a direct loss of material due to erosion. These factors combined with often inadequate salvage efforts have made the task of rehabilitation more difficult.

Simply resspreading this material over resloped ground is one step toward reclamation. In areas where erosion was not an anticipated factor and therefore rapid revegetation not as essential rehabilitation has been limited to resspreading of material. Other areas had no topsoil salvaged and sloping without the application of organics was carried out. This may be seen as a minimal effort but is certainly an improvement over past practices.

PROCEDURES

It was recognized that successful revegetation could only be carried out in most locations if soil quality deficiencies were addressed. At selected locations requiring rapid green-up soil treatment consisted of the application of agricultural limestone and fertilizer before grass and/or native trees were planted.

In areas where limestone was used to treat soils it was spread by hand at a rate of approximately 70 kg/100 m². This was followed by the application of various mixtures of dry chemical

fertilizers at a rate of approximately 56 kg/ha. Fertilizers with different ratios of nitrogen, phosphate, and potassium (N-P-K) were used depending on soil analysis. The idea was to promote rapid and lush growth of a grass seed mixture consisting of 55% creeping red fescue, 25% annual rye, 15% Kentucky blue and 5% white clover. Seed mixtures were used since we did not know how these individual grasses would respond in the harsh environment. Creeping red fescue is hardy, has lower nutrient demands and will germinate in relatively cool temperatures. Annual rye is easily established and stabilizes soil surfaces early in the growing season. The fibrous root system of Kentucky blue aids in soil stability and the white clover is a known nitrogen fixer (quoted from Newfoundland and Labrador Hydro, 1984).

Following grass seeding conducted to halt immediate erosion and to protect soils from drying out, a number of areas were planted with native tree seedlings. These were usually black spruce (*Picea mariana*). Some larch (*Larix laricina*) were also planted. Some large areas at the Upper Salmon development were not grass seeded before tree seedlings were planted.

Subsequent site inspections have shown that there is limited success with the spruce and larch. This is especially evident where grass was not planted first. It appears that the early introduction of spruce and larch into disturbed areas has questionable value. In natural systems these large trees occupy one stage in a community succession and it would appear that the intermediate steps of moss, sedge and shrub cover cannot be bypassed with any realistic chance at long term success. The system must, ideally, develop through stages before conditions are met that would allow survival of these large species.

Factors that may contribute to this limited success also include the lack of adequate shelter for newly transplanted seedlings, the shock of transplanting, planting conditions on the day in question (i.e. hot dry weather could cause immediate mortality) and poor nutrient availability.

Even under ideal conditions we cannot assume that these disturbed areas will eventually evolve into the same plant community structures that existed prior to disturbance. It will be interesting and informative to monitor these sites during future years to determine what sort of communities develop. Hydro has proposed that audits be conducted to document the level of reclamation success. This will help to improve rehabilitation on future proposals and highlight any need for further action on the existing sites.

The feasibility of planting clumps of speckled alder (*Alnus rugosa*) and mountain alder (*Alnus crispa*) is being examined. It is hoped they will be able to rapidly invade recently exposed soils.

LEGISLATION

It is apparent to everyone involved in reclamation at the Upper Salmon and Cat Arm developments that the success of any such

program depends largely on steps that must be taken early in the process. The eventual rehabilitation of disturbed lands must be considered an important project component by resource developers and their contractors.

The Government of Newfoundland and Labrador is in the process of developing regulations that will require minimum rehabilitation efforts on any resource development. The regulations being developed will be implemented under the Environmental Assessment Act.

It is presently proposed that an advisory board be established consisting of government, industry, public and academic members. This Board would report to the Minister of Environment on matters concerning rehabilitation.

Government is also exploring the concept of a performance bond to be required of developers prior to project approval. This bond will be used to undertake rehabilitation work in cases where the developer has failed to do so. A rehabilitation certificate will be issued by the Minister of Environment when a proponent is released from any further rehabilitation work on a specific undertaking.

CONCLUSION

In my position as an Environmental Surveillance Officer at various construction sites I have clearly seen the need for enacted regulations concerning rehabilitation. But legislation is only one part of the process. Regulations will mean nothing if the dozer operator stripping an area of land has no concept of what is required after the resource has been exploited. It is not enough to legislate, we must also educate. I believe that proponents and governments must be responsible for ensuring that contractors are aware of proper procedures to be followed. If soil is lost it is lost forever. The regulations proposed will play a large part in promoting responsible use of our land but they will not work without cooperation based on understanding from the people actually operating the equipment.

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FOREST HARVESTING IMPACTS ON
WATERSHED VALUES

L.H. Powell

Department of Fisheries and Oceans
Vancouver, B.C.

ABSTRACT

A slide presentation about the Carnation Creek Watershed study - a multi-agency interdisciplinary project: to establish an understanding of ecological processes and physical and biological interactions in a typical small watershed in a west coast rain forest area; to obtain information on the effects of specific logging and post logging treatments on such a system; and to communicate research information to forest and fishery managers and planners. The presentation will concentrate on the stream morphology segment of the project and will describe some of the impacts of forest harvesting that have been observed so far on this small west coast rain forest watershed.

GUIDE TO SWAIN
THE SOILS AND WATER ACTIVITY INVENTORY

D.R. Murray and J.R. Hardy

Resources and Environment Section
Regional Development Branch
Agriculture Canada, Ottawa

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ABSTRACT

Soil degradation and water pollution are of significant concern to the agricultural community. An increasing amount of activity in Canada has been directed in the last 5 years towards these topics as well as towards soil and water improvement, conservation and reclamation. A computerized inventory has been developed by the Resources and Environment Section in order to identify and describe the various activities that are currently underway. This guide outlines the data contained in this inventory, its organization and use.

INTRODUCTION

The agricultural industry recognizes a number of soil and water problems related to current farming practices. An increasing amount of effort has been directed towards these problems in various forms. Specific projects, regional programs and government policies have focused attention on these problems and their solutions. These problems are common to several other disciplines such as those involved in mining, forestry, building construction, highways and energy. They have directed extensive efforts towards similar problems and devising solutions for their specific needs. A compilation of information about efforts would be useful to both government and private sectors. Management and field personnel would benefit from the activity listing. Management would like to know what, how and by whom, work is being done. Field personnel would like to know who is currently working on a specific problem and is available to discuss technical details.

To address this need in Canada, SWAIN has been prepared. Each activity has been entered as a separate entry or record in the data base. Each record contains details about the activity. Explanatory information about each entry is provided for policies, programs or projects that are not necessarily published. The activity also must be currently underway. Once an activity ceases to be current, it is removed from the active file to an archive file. Each record includes a series of key word identifiers. SWAIN however, also records descriptive information about the activity and its progress.

It is hoped that the inclusion of additional information, although brief at times, will be beneficial to those concerned with a soil or water problem. This publication is designed to explain what information has been gathered into the data base inventory and how the inventory can be used to assist in the solution of soil and water problems. As a guide to the inventory, this publication will describe the data base using the headings listed below.

- A Information Collected
 - A.1 ACTIVITY DESCRIPTION - what type of information has been obtained
 - A.2 CONTRIBUTORS - the general perspective of the activity as it relates to other entries in the data base
 - A.3 NUMERICAL DATA - organizations that are contributing to the activity
 - A.4 TEXT - numeric values on funding, manpower and duration of the activity
- B Descriptive Terms Used - narrative information that describes the activity and its progress
- C Record Filing - the terms used to describe the information to clarify any differences between word usage by varied disciplines
- a description of the data base records and how information is filed within each record and in

- C.1 RECORD LAYOUT
 - the data base
 - a sample record to illustrate the types of information contained and how they could be arranged
- C.2 CODING SYSTEM
 - the numerical coding of key words to facilitate the filing and retrieval of the record information
- C.3 DESCRIPTION
 - a narrative summary of the activity expressed under the headings listed in Appendix 1
- C.4 DATA BASE FORMAT
 - the technical arrangement of the data on the D-Base III file
- D Data Base Use
 - how to use the inventory to answer specific requests
- D.1 ITEMIZE REQUEST
 - clarification of details of request
- D.2 SELECT FIELDS
 - selection of fields that contain the desired information
- D.3 SELECT CODING
 - selection of coding within the desired fields to extract the specific information needed
- D.4 SELECT OUTPUT
 - decision of how the output is to appear
- D.5 SUBMIT REQUEST
 - preparation of request in writing and submit to the data base developers

METHODOLOGY

The data for the inventory has been gathered through personal communication and published information in the case of government programs. Updating and verification of the information has been through the Regional Offices of Agriculture Canada or direct contact with the contributor. As SWAIN becomes fully operational a more organized data gathering and upgrading will be presented. The current process is attempting to catch the range of potential contributors and users on which a structure can be designed.

The present 196 entries are believed to represent only a part of the wide range of activities currently underway. This Guide to SWAIN is to provide a first step at developing a suitable example to which others can compare their work and its suitability for inclusion in the data base.

A Information Collected

The inventory is composed of unique entities called activities. Each activity forms a file of information related to a soil and water problem or concern. All activities are separated into three levels represented as projects, programs or policies. The activity record contains information which describes the specific characteristics of the activity. The information falls into four categories: activity description, contributors, numerical data and text.

A.1 ACTIVITY DESCRIPTION

The activity is given a unique identification number. It is also described in general terms to indicate the scope, thrust, locations, the number of contributions and how it relates to other entries.

A.2 CONTRIBUTORS

Each contributing organization is described in view of its type and subject of interest. An address and contact are given for each organization where applicable. In cases where more than 4 organizations are participating, the first three are described in detail, while those remaining are combined in the fourth group "Other".

A.3 NUMERICAL DATA

Funding and manpower values are recorded for the activity in thousands of dollars and person years, respectively. Three categories are used: total expectations over the life of the activity; current year allocation from these totals, and; the amounts used of the totals to the date of the last edit. To complement this, the time frame includes the start, end and edit dates. A flag date is also included if another date is critical to the file updating process. (e.g. a progress report pending prior to end date).

A.4 TEXT

Text information is included under a number of headings (called fields) including Title, Client, Objective, Method, Reason, Progress, Reference and Comment. Each field is used, as necessary, to give a clear understanding of the activity and its intent. This information is used to select key words to describe the approach taken to address a specific problem or to encourage a desired practice. The keyword system will be described in more detail under "RECORD FILING".

B Descriptive Terms Used

Terminology often poses problems since many contributors interpret various concepts in different ways. For this reason, definitions of keywords are given in a glossary of terms (Appendix 1) as they apply to this inventory. If additional terms are used on a record, they will be described in the "Comments" field of that record entry.

C Record Filing

C.1 RECORD LAYOUT

Table 1 gives an overview of the layout of an activity record. This layout facilitates the presentation of the key information regarding the activity. For more details of the data base format see section "C.4". The activity record consists of

TABLE I
ACTIVITY RECORD

RECORD IDENTIFICATION					S	L	#										
I D N U M	L	R	R	P	C	O											
					P	O											
					P	C											
					E	O											
					I	A											
					O	R											
					N	G											
							</										

both a text description and a coded description. The text description contains both narrative and numeric information about the activity. The coded description contains a numeric representation of key words indicating who is involved, where the work is occurring and what is being done. Each field will be described as it appears on Table 1 starting at the top left.

The activity record starts with a RECORD IDENTIFICATION. This consists of two numbers: a four digit identification number and a one digit activity level number. It could be one of three levels: project, program or policy. A numeric coding is used for this such as "1" for project (see Table 2). There is space allotted for the inclusion of the identification number of other activities that are hierarchically related to the activity being described.

The two fields, SCOPE and LOCATION use the coding numbers in Table 2 to describe the geographic extent of the activity and its location. For example a scope of "4" would indicate a provincial activity. A location might be designated as "3512" which would indicate the province as Ontario (35) and the census division as (12). When activity is occurring at more than one location, information is given for the headquarters location of the activity only.

The next field, # OF ORG, refers to the actual number of organizations that are participating in the activity. This provides an indication of how much information is contained in other parts of the record. It also enables separation of the contributions by different organizations.

The fields, FUNDING, MANPOWER, and DATES contain information about the cost and time frame of the complete activity. The values in these fields represent the sum total of all contributing organizations. The values for up to four individual contributing organizations are expressed elsewhere as explained below.

Under the heading of ORGANIZATION, there are spaces for four entries. The first would be the lead organization followed by three more in their order of participation. For each entry the terms "type, department, and subject" are included to facilitate the grouping of similar organizations. The coding for these is outlined in Table 2. As an example, an organization can be coded numerically as "2 4 10"; this would be interpreted as a Provincial government (2), Department of Agriculture (4), involved in extension (10). The funding and manpower contributions are recorded for each entry as they contribute to the total described earlier.

The fields, APPROACH, PROBLEM and PRACTICE are composed entirely of numerical coding from Table 2. An explanation of this coding follows in section "C.2".

The remaining fields on the record entry are all narrative in format, reduced to a convenient size and style to permit comparison between records. These fields follow the intent

TABLE 2
NUMERICAL CODING

RECORD IDENTIFICATION

NUMBER	sequential 4 digit number	
LEVEL	1	Project
	2	Program
	3	Policy
PROJECT PROGRAM POLICY	the record number of a related activity	

SCOPE

1	International
2	Federal
3	National Region
4	Provincial
5	Regional
6	Local

LOCATION

PROVINCE	10	Newfoundland
	11	Prince Edward Island
	12	Nova Scotia
	13	New Brunswick
	24	Quebec
	35	Ontario
	46	Manitoba
	47	Saskatchewan
	48	Alberta
	59	British Columbia
	60	Yukon
	61	Northwest Territories

CENSUS DIVISION	01-10	for Nfld
	01-03	for PEI
	01-18	for NS
	01-15	for NB
	01-98	for QC
	01-60	for Ont
	01-23	for Man
	01-18	for Sask
	01-15	for Alta
	01-57	for BC
	01-	for YT
	01-	for NWT

ORGANIZATION

TYPE	1	Federal Government
	2	Provincial Government
	3	Municipal Government
	4	University
	5	Industry
	6	Association/Authority
	7	Individual

DEPARTMENT	1	Agriculture
	2	Forestry
	3	Environment
	4	Natural Resources
	5	Mining

SUBJECT	01	Administration
	02	Production
	03	Research
	04	Regional Development
	05	Plant
	06	Soil
	07	Water
	08	Environment
	09	Geography
	10	Extension

APPROACH

DIRECTION	100's	Conservation
	200's	Improvement
	300's	Reclamation
	400's	Identification

MEANS

Support	20's	1	subsidy
		2	grants
		3	contracts
Collection	40's	1	survey
		2	monitoring
Study	50's	1	basic research
		2	applied research
		3	technology development
Extension	60's	1	technology transfer
		2	demonstration
		3	conference
		4	workshop/tour
Other	90's	1	legislation

PROBLEM

CONDITION	500's	Limitation
	600's	Degradation
	700's	Unknown

SUBJECT

Chemical	10's	1	acidity
		2	salinity
		3	nutrient
		4	pH
Physical	20's	1	wind erosion
		2	water erosion
		3	compaction
		4	stoniness
		5	disturbance
		6	organic matter

Biological	30's	1	subsidence
		2	plant residues
Climatic	40's	1	frost
		2	soil temperature
		3	soil aeration

Water	50's	1	excess soil water
		2	lack of soil water
		3	ground water
		4	surface water
		5	pollution
Economics	60's	1	cost
		2	land use change

Crop	70's	1	yield loss
		2	soil capability

Other	90's	1	soil properties
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PRACTICE

RECIPIENT

800's	Resource
900's	Production

ACTION

Land	1	land forming
Modification	2	terracing
10's	3	land clearing
	4	texture change
	5	ridging

Cultivation	20's	1	no-till
		2	minimum till
		3	conservation tillage
		4	strip tillage
		5	subsoiling

Management	30's	1	cover crop
		2	manure handling
		3	residue management
		4	intercropping
		5	soil management
		6	rotation
		7	contour cropping

Soil Additives	40's	1	mulching
		2	liming
		3	green manure
		4	sewage sludge
		5	fertilizer

Drainage	50's	1	sub surface drainage
		2	surface drainage
		3	diversion
		4	grassed waterway

Structures	60's	1	dugouts
		2	dams
		3	wells
		4	floods
		5	pumping
		6	ditches

Protection	70's	1	snow trapping
		2	windbreaks
		3	erosion control
		4	forage seeding

Irrigation	80's	1	water application
		2	water management

Other	90's	1	awards
		2	mapping
		3	workshop/tour
		4	conference
		5	education

expressed in Appendix 1, page V. An explanation of this part of the record is described in section "C.3".

C.2 CODING SYSTEM

The numerical coding is provided in Table 2. Within each field there are potentially six entries of twin - 3 digit numbers. The first 3 digits represent the key word combinations desired, while the second 3 digits represent the percentage that they contribute to the activity. Examples are 262/050, 554/080, and 853/020 for the approach, problem and practice respectively. The 262/050 would be interpreted as an activity that has an approach direction of improvement by the means of extension and more specifically demonstration. This approach is 50% of the emphasis of the activity. The activity would therefore have other numerical groupings to explain how the remainder is used. Similarly the second example of 554/080 would be interpreted as a problem that was considered a limitation condition within the subject area of water and more specifically surface water. The activity concentrates 80% of its effort in this problem area. The final example of 853/020 would be interpreted as the practice that was for the resource as the recipient with the action of drainage being most important, and more specifically diversion being the end practice. However, this is only 20% of the practices aimed at by the activity. For each field there could be unlimited combinations of key words to describe the activity. Each contributing organization can have two such keyword groupings attached specifically to its efforts.

A special feature of the coding is that the use of a "0" indicates all key words in that grouping apply. For example, the use of 850 as a practice would include all drainage practices (including 851, 852, 853 and 854). In any field where a number is to be reported and there is no known information, the field will be blank or filled with 9's. As a result, if a "0" occurs in a data field it will be used as a true value.

C.3 DESCRIPTION

The remaining fields, Title, Contact, Client, Objective, Method, Reason, Progress, Reference, Address and Comment are all narrative. The information is reduced to a convenient size and style to permit comparison between records. The contents of these fields follow the definitions given in the glossary of terms (Appendix 1). As much information as possible is included in this section to explain the activity. In some cases it is necessary to abbreviate the submitted information to fit in the space available and for consistency.

C.4 DATA BASE FORMAT

The inventory records are stored on WANG floppy disks for printing out record entries and on an IBM Personal Computer for use with D-Base III software. The format of the information fields is outlined in Table 4.

The D-Base III file is structured around field names, type,

width, and number of decimals. The field name is a unique 9 character identifier for a maximum of 128 fields. "Type" refers to the type of storage, be it numeric, character or memo. Numeric contains only numbers while character contains letters and numbers. The memo field is an extended character field in the form of a word processor that is stored separately within D-Base III text file, and the contents of a memo field can be used in searches and outputs. The field width indicates the number of spaces allocated for that field with the associated decimals as necessary.

To assist in understanding the data base format, an explanation is necessary to join the fields discussed in Appendix 1, Table 1 and Table 2, with the field names used by D-Base III and illustrated in Table 4. Twenty (20) abbreviations are used. These are listed in Table 3. Where abbreviations are used for suffixes or prefixes, there are alternates indicated for 9 of those listed. Several examples follow to illustrate how abbreviations are used. TFUNDS would give the total funds allocated for the activity. ORG2TF would give the total funds that are allocated for the activity by organization 2, or the second most involved organization. ORG3APP1 would indicate the primary or most important approach considered by organization 3. APP1 by itself would be the most important approach for the entire activity with no connection to an organization. PRAC5 would be the fifth most important practice for the activity while CPERCENT5 would be the percent of effort of the activity that is being spent on practice number 5. A final example is ADDRESS2 which would be the address of organization 2. For fields that are not abbreviated the names are self explanatory.

D Data Base Use

D.1 ITEMIZE REQUEST

A review of the tables and figures of this report will give an indication of the information that is currently available within the data base. The first requirement of the user is to determine if the information contained and its format is of value to his or her specific needs. Before proceeding, a clear statement of the request should be prepared. Additional information (e.g. cumulative PY or \$ totals) by subject can be generated from the data base to meet specific needs.

D.2 SELECT FIELDS

Using the detailed request objective, the fields that contain the required information can be selected from the data base. Appendix 1, Table 1 and Table 3 can be used to assist in this selection.

D.3 SELECT CODING

Within the desired fields, selection of coding can be done to isolate the specific information needed to meet the request. The coding system in Table 2 can be used in this stage.

TABLE 3
FIELD NAME ABBREVIATIONS

DESCRIPTION	ABBREVIATION	ALTERNATE WHEN USED AS SUFFIX OR PREFIX
<u>I</u> dentification <u>N</u> umber	IDNUM	ID
<u>N</u> umber as in how many	N	
<u>P</u> roject	PROJ	
<u>P</u> rogram	PROJ	
<u>P</u> olicy	POL	
<u>D</u> epartment	DEPT	
<u>S</u> ubject	SUBJ	
<u>T</u> otal	T	
<u>C</u> urrent <u>Y</u> ear Allocation	CY	
<u>S</u> pent to date	S	
<u>U</u> sed to date	U	
<u>F</u> unds	FUNDS	F
<u>P</u> erson <u>Y</u> ear	PY	
<u>O</u> rganization	ORG	
Lead <u>O</u> rganization	ORG1	<u>1</u>
2nd <u>O</u> rganization	ORG2	<u>2</u>
3rd <u>O</u> rganization	ORG3	<u>3</u>
4th <u>O</u> rganization	ORG4	<u>4</u>
<u>A</u> pproach	APP	A
<u>P</u> roblem	PROB	B
<u>P</u> ractice	PRAC	C
Priority of Approach, Problem and Practice	I TO 5	

Table 4
Data Format

FIELD	FIELD NAME	TYPE	WIDTH	DECIMAL
Record Identification				
Number	IDNUM	numeric	4	
Level	LEVEL	numeric	1	
Project	PROJID	numeric	4	
Program	PROGID	numeric	4	
Policy	POLID	numeric	4	
Scope	SCOPE	numeric	1	
Location	LOCATION	numeric	4	
Number of Organizations	MORG	numeric	2	
Funding('000 dollars)				
Total	TFUNDS	numeric	7	
Current year annual	CYFUNDS	numeric	7	
Spent to date	SFUNDS	numeric	7	
Manpower(Person years)				
Total	TPY	numeric	4	1
Current year annual	CYPY	numeric	4	1
Used to date	UPY	numeric	4	1
Dates(Month and year)				
Start	START	numeric	4	
End	END	numeric	4	
Edit	EDIT	numeric	4	
Flag	FLAG	numeric	4	
Organization descriptions for organizations 1 to 4				
Type	ORGNTYPE*	numeric	1	
Department	ORGNDPT	numeric	1	
Subject	ORGNSUBJ	numeric	2	
Total funding	ORGNTF	numeric	7	
Current year annual	ORGNCYF	numeric	7	
Spent to date	ORGNSF	numeric	7	
Total person years	ORGNTPY	numeric	4	1
Current year annual	ORGNCYPY	numeric	4	1
Used to date	ORGNUPY	numeric	4	1
Approaches	APPM**	numeric	3	
from 1 to 5	m = 1 to 5			
percentage emphasis	APERCENTm	numeric	3	
for approaches 1 to 5	m = 1 to 5			
	A_OTHERS	numeric	60	
organization approach	ORGNAPO***	numeric	6	
for organization 1 to 4	n = 1 to 4			
for approach 1 to 2	o = 1 to 2			
Problems	PROBm	numeric	3	
from 1 to 5	m = 1 to 5			
percentage emphasis	BPERCENTm	numeric	3	
for problems 1 to 5	m = 1 to 5			
	B_OTHERS	numeric	60	
organization problems	ORGNPROBn	numeric	6	
for organization 1 to 4	n = 1 to 4			
for problems 1 to 2	o = 1 to 2			
Practices	PRACn	numeric	3	
from 1 to 5	m = 1 to 5			
percentage emphasis	CPERCENTm	numeric	3	
for practices 1 to 5	m = 1 to 5			
	C_OTHERS	numeric	60	
organization practices	ORGNPRACn	numeric	6	
for organization 1 to 4	n = 1 to 4			
for practices 1 to 2	o = 1 to 2			
Title	TITLE	character	120	
Contact for organizations 1 to 4	CONTACT_n	character	120	
	n = 1 to 4			
Client	CLIENT	character	120	
Objective	OBJECT	Memo	10	
Method	METHOD	Memo	10	
Reason	REASON	Memo	10	
Progress	PROGRESS	Memo	10	
Reference	REFERENCE	Memo	10	
Address of organizations 1 to 4	ADDRESS_n	Memo	10	
	n = 1 to 4			
Comment	COMMENT	Memo	10	

* n = 1 to 4

** m = 1 to 5

*** o = 1 to 2

D.4 SELECT OUTPUT

There are a number of ways that the information can be displayed and manipulated. To meet the specific needs of the request an outline of the expected products should be prepared. The space limitations of the printed page should be kept in mind at this stage. Table 4 would be helpful in determining the appropriate page size to display the output. Appendix 2 gives some examples of output products.

D.5 SUBMIT REQUEST

The final step is to prepare the request in writing and submit to the data base developers. If there are difficulties in any of the above steps, then the authors will be able to assist in preparing a final product that contains the required information in a form that meets the needs of the client.

ACKNOWLEDGEMENTS

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APPENDIX I

GLOSSARY OF TERMS

RECORD IDENTIFICATION

- NUMBER - the number assigned to each activity as a unique identifier
- LEVEL - the hierarchy of activity as project, program or policy
- PROJECT - the activity with specific goals and resources that represent the most basic unit of work
- PROGRAM - a group of projects of similar goals and resources
- POLICY - an activity involving a number of programs

SCOPE

- International - Involves participation from outside Canada
- Federal - Involves all of Canada
- National Region - Involves a group of provinces of Canada
- Provincial - Involves one province
- Regional - Involves part of a province
- Local - Involves only a local area

LOCATION

- the location of the activity by province and census division within that province using Census of Canada codes

OF ORG

- the number of organizations participating in the activity

FUNDING

- Includes funds that are directed towards the activity by the participating organizations including grants, capital, operating, contract and administration

- ACTIVITY TOTAL - total funds allocated for entire life of activity
- CURRENT ANNUAL - amount of funds allocated for the current fiscal year
- SPENT TO DATE - accumulated expenditures since start date

MANPOWER

- Includes person years directed towards the activity (PY classification is not considered)

- ACTIVITY TOTAL - total personnel allocated for the entire activity
- CURRENT ANNUAL - number of personnel allocated for the current fiscal year
- USED TO DATE - accumulated person years since start date

DATES

- START - when work started
- END - when work is to be completed
- EDIT - when the record was last edited or corrected
- FLAG - when the record should be reviewed

ORGANIZATION

- the description of each contributor in the order of leadership priority as LEAD, 2nd, 3rd, 4th or OTHER

- TYPE - major administrative entity
- DEPARTMENT - major division within the organization type
- SUBJECT - dominant subject area of the involved department

APPROACH

- the approach taken by the activity described under 2 headings: DIRECTION and MEANS

- DIRECTION - the intent of the activity towards the resource
- Conservation - the process of maintaining the resource
- Improvement - the process of changing the resource to a better condition than presently exists

<u>Reclamation</u>	- the process of returning disturbed or derelict land to a productive use
<u>Identification</u>	- the process of determining the situation or condition of the resource
<u>MEANS</u>	- the means of performing the activity
<u>Support</u>	- type of financial assistance given to the activity
grants	- fixed amount given without strict reporting needs
subsidies	- percentage assistance in joint participation
contracts	- fixed amount given with detailed reporting requirements
<u>Collection</u>	- the process of obtaining information
survey	- collecting new information at one point in time
monitoring	- collecting the same information over time to document any change
<u>Study</u>	- the type of examination given the data collected
basic research	- the theoretical examination of a situation or condition
applied research	- the practical application and examination of theory
technology	- the improvement of equipment or techniques to permit field application of research
development	
<u>Extension</u>	- the methods used for information transfer to end users
technology	- the technical information exchange process
transfer	
demonstration	- field examples of techniques for viewing by potential users
conferences	- large group meetings for the exchange of ideas
workshop/tour	- group meetings including field days, seminars, workshops and tours
<u>Other</u>	
legislation	- regulations to encourage or discourage certain practices
 PROBLEM	 - the problem addressed by the activity described under two headings: CONDITION and SUBJECT
<u>CONDITION</u>	- the impact of the problem being considered by the activity
<u>Limitation</u>	- the condition that restricts the use of the resource, commonly a natural phenomenon
<u>Degradation</u>	- the process of deterioration of the resource, commonly the result of man's activities
<u>Unknown</u>	- the specific problem is not known
<u>SUBJECT</u>	- the problem being addressed by the activity
<u>Chemical</u>	- the chemical components or condition of the soil resource excluding water
acidity	- the soil pH reaction and buffering capacity
salinity	- the accumulation of salts in the soil profile
nutrients	- the fertilizers, chemical elements and compounds needed for plant growth
pans	- the compacted, impervious layers within a soil resulting from chemical reactions
<u>Physical</u>	- the physical features or condition of the soil
wind erosion	- movement of soil by wind action
water erosion	- movement of soil by water action
compaction	- the increase in soil bulk density as a result of heavy equipment use or inappropriate timing of field traffic
stoniness	- the existence of excess stones
disturbance	- the mixing and disruption of the soil profile resulting from construction or excavation activity
organic matter	- the organic fraction of the soil that includes plant and animal residues at various stages of decomposition

<u>Biological</u>	- the living component of the soil that uses the soil organic matter and chemical nutrients
subsidence	- the downward movement of the ground surface caused by solution and collapse of the underlying material as a result of microbial activity in the organic material
plant residue	- the material remaining on and in the soil following the harvest of a crop
<u>Climate</u>	- the macro-, meso- and micro-environmental conditions that impact on the resources and crops
frost	- the condition that exists when air temperature drops to 0°C or lower, but which may or may not result in freeze damage to crops
soil temperature	- the degree of hotness or coldness of the soil at a given time
soil aeration	- the exchange of gases between the atmosphere and the soil pores
<u>Water</u>	- the fluid resource, H ₂ O
excess soil water	- too much water in the soil profile
lack of soil water	- not enough water in the soil profile
ground water	- the subsurface water in the zone of saturation.
surface water	- the water whose surface is exposed to the atmosphere including runoff
pollution	- the contamination of the water resource
<u>Economics</u>	- the expenses associated with the resource and its use
costs	- the direct expenditure of funds
land use change	- the indirect costs related to the resource potential
<u>Crop</u>	- the product or output which is being produced using available resources
yield	- the amount of crop production per unit area either removed for use elsewhere or remaining as crop residue
soil capability	- the ability of the soil to support a desired crop

PRACTICE

RECIPIENT	- described under two headings: RECIPIENT and ACTION
<u>Resource</u>	- to area to which the practice is directed
<u>Production</u>	- the soil or water available for use
ACTION	- the output from the use of the resource
<u>Land Modification</u>	- the expected result of the activity efforts
land forming	- the surface of the soil is altered from its present state as a major effort and commitment to future use of the resource
terracing	- the shaping of the land surface to permit better movement of water and machinery
land clearing	- the construction of embankments and channels across a slope to control erosion
surface texture	- The removal of trees, shrubs and rocks to change the land use
ridging	- the alteration of the soil surface roughness to change its susceptibility to wind or water erosion
<u>Cultivation</u>	- the creation of parallel raised mounds of soil, creating raised ridges and troughs
no-till	- the manipulation of the soil material to incorporate material or to prepare the surface for the planting of a crop
minimum tillage	- the method of planting crops that involves no seedbed preparation other than opening the soil for the purpose of placing the seed at an intended depth
conservation tillage	- the least soil manipulation necessary for crop production or meeting tillage requirements under the existing soil and climatic conditions
	- the tillage sequence that reduces loss of soil or water relative to conventional tillage

strip tillage	- the tillage operations for seedbed preparation that are limited to a band not to exceed one-third of the distance between rows; the area between is left untilled
subsoiling	- the tillage of subsurface soil without inversion, for the purpose of breaking up dense layers that restrict water movement and root penetration
<u>Management</u>	- the organization, planning and supervision of an activity
cover crop	- the crop grown primarily for the purpose of protecting and improving soil between periods of regular crop production
manure handling	- the beneficial use and means of dealing with animal wastes
residue management	- the beneficial use and means of dealing with the plant material remaining after crop harvest for the improvement or protection of the soil
intercropping	- the planting of one crop between the rows of another on the same land
soil management	- the beneficial use and means of dealing with the soil resource
rotation	- the regular alteration of land use for the purpose of improving the soil, controlling disease or changing the crop produced
contour cropping	- the layout of crops in comparatively narrow strips in which the farming operations are performed approximately on the contour
<u>Soil Additives</u>	- the material added to the soil to increase crop yield, or improve the soil
mulching	- the addition of natural or artificial layers of materials that aid in soil stabilization or moisture conservation
liming	- the addition of calcium carbonate to alter the soil reaction (pH) and improve crop yield
green manure	- the living vegetation that is used as an incorporated mulch
sewage sludge	- the municipal waste material that has received some primary treatment
fertilizer	- the materials that are used for the purpose of providing nutrients for crop production, commonly including nitrogen, phosphorus and potassium
<u>Drainage</u>	- the removal of excess surface water or groundwater from land by surface or subsurface drains
subsurface drainage	- the use of tile drains to remove subsurface water from the land
surface drainage	- the use of structures on the surface of the land to remove water
diversion	- the channel, embankment, or other man-made structures constructed to redirect water from one area to another
grassed waterway	- the natural or constructed diversion covered with erosion-resistant grass cover used to conduct surface water from or through cropland
<u>Structures</u>	- the structures that have been designed and constructed to do a specific function
dugouts	- the excavation made for the purpose of storing surface water for later use
dams	- the barrier to confine or raise water for storage or diversion, to create a hydraulic head, to prevent erosion or for the retention of soil, rock or other debris
wells	- the means of obtaining water from the subsurface groundwater
fills	- the unconsolidated material commonly used to improve drainage of engineered structures
pumping	- the movement of water from one level to another using a mechanical device
ditches	- the open excavations commonly used for the movement of water from land

<u>Protection</u>	- the techniques that prevent the resource from being damaged
snow trapping	- the catching of snow and holding it in place to encourage infiltration of the water when it melts
windbreaks	- the growing of plant material or the construction of barriers that will reduce the velocity of the wind on its' lee side
erosion control	- the combination of structures and practices that help reduce water erosion impact on the soil
forage seeding	- the establishment of forages to prevent wind or water erosion and other potential damage to the resource
<u>Irrigation</u>	- the application of water to lands for agricultural purposes
water application	- the means selected for applying water to an area
water management	- the application of practices to obtain added benefits from precipitation, irrigation, drainage and water storage
<u>Other</u>	
awards	
mapping	
workshop/tour	
conference	
education	
 TITLE	 - the name by which the activity is known
 CONTACT	 - the name, position title, organization affiliation and telephone number of the person from whom information about the activity can be obtained
 CLIENT	 - the individual, group or organization for whom the work is being done or the potential beneficiary of the results
 OBJECTIVE	 - an outline, including milestones, of what work is to be done to address a problem
 METHOD	 - the procedure or technique that will be used to meet the objectives
 REASON	 - the justification for why the activity is being undertaken
 PROGRESS	 - a statement of the condition of the work at the edit date in relation to the objectives and milestones
 REFERENCE	 - the full reference of any document resulting from an activity
 ADDRESS	 - the full name and address of all contributing organizations
 COMMENTS	 - additional information that is not applicable to any other category

APPENDIX 2
EXAMPLES OF OUTPUT

RECORD IDENTIFICATION					S	L	#										
					C	O											
					O	C	O										
I	L	R	R	P	P	A	F										
D	E	O	O	O	E	T											
N	V	J	G	L		I	O										
U	E	I	I	I		O	R										
M	L	D	D	D		N	G	ACTIVITY	CURRENT	SPENT	ACT	YEAR	TO	START	END	EDIT	FLAG
								TOTAL	ANNUAL	TO DATE	TOTAL	ANNUAL	DATE				
476	I	476	230	342	4	3539	3	300	100	150	10.0	3.5	5.5	8504	8703	8605	8612

			T	D	S													
			Y	E	U													
ORGANIZATION			P	P	B													
			E	T	J													
LEAD ORGANIZATION			2	1	10				200	0	100	2.0	0.0	2.0				
2nd ORGANIZATION			4	1	6				100	0	50	1.0	0.0	0.0				
3rd ORGANIZATION			5	5	6				0	0	0	7.0	3.5	1.5				
4th or OTHERS									9999999	9999999	9999999	99.9	99.9	99.9				

APPROACH :262/080 360/020

PROBLEM :520/100

PRACTICE :840/050 870/025 853/025

TITLE :Reclamation of agricultural land

CONTACT	:	Name	Mr. P. Jones	Dr. N. Moore	Mrs. J. Bradford
		Position	Director	Head, Soils Section	Field Supervisor
		Affiliation	Agriculture Canada	University of Guelph	A. Industries Ltd.
		Telephone number	613-990-xxxx	519-223-xxxx	446-664-xxxx

CLIENT :Pit and quarry operations, cash crop farmers and agriculture extension staff.

OBJECTIVE :To improve the ability of the agriculture sector to use the information that is available from the mining industry in the correction of their soil limitations and degradation problems.

METHOD :To set up a series of demonstrations, workshops and seminars to show how it can be implemented.

REASON :Soil erosion has been a problem to mining as well as agriculture and it is necessary to share the experiences of both disciplines.

PROGRESS :Five demonstration sites have been established. Three workshops were held and a progress report was published.

REFERENCE :Bradford, J. 1986. Progress in Reclamation. Environmental Journal No.35 Vol.45

ADDRESS	:	Name	Agr. Canada	Soils Section	A. Industries Inc.
		Address	Regional Dev. Br.	University of Guelph	Minesite, Ontario
			S J C B	Guelph, Ontario	K4X 2E3
			Ottawa, Ontario	R2P 4X5	
			K1A 0C5		

COMMENT :The workshops have been well received and it is being recommended that the project be continued beyond its end date. A proposal will be released Dec. 1986

VEGETATION RESPONSE TO RIGHT-OF-WAY CLEARING
PROCEDURES IN COASTAL BRITISH COLUMBIA

Ann B. McGee

Graduate Student, Faculty of Forestry,
University of British Columbia

ABSTRACT

B.C. Hydro designates four clearing standards for the initial clearing of transmission line rights-of-way (ROW). These clearing standards are differentiated on the basis of the type of equipment used and the amount of vegetation removed, and impose different levels of disturbance on the cleared sites. The subsequent development of vegetation on these cleared sites is a function of this disturbance. Residual vegetation, viable seed stored in the soil, and dispersed seeds also affect subsequent successional community development and composition.

The objectives of this research project were to assess the numbers and species of seed stored in forest soils of coastal B.C., and to compare the germination of these seeds under greenhouse (an environment which promotes maximum germination) and field (where moisture and temperature fluctuations are more similar to natural conditions) regimes.

Soil samples were collected from dry, intermediate, and moist ecosystems in undisturbed forest, low disturbance ROW sites, and high disturbance ROW sites (9 different ecosystem x disturbance combinations). Samples from the forest were collected from the forest floor, and 0-5 and 5-10 cm depths in the mineral soil. For low disturbance ROW plots, forest floor and 0-5 cm mineral soil were collected. Samples from each layer were subdivided and placed in plastic trays, with 5 subsamples located in a greenhouse and 5 in an experimental field. All samples were watered daily.

In forest samples, 90% of the stored seed germinated from the forest floor layers and the number of seeds germinating decreased with depth. Intermediate and moist sites had more viable stored seeds than did dry sites. Field germination was only 56% of greenhouse germination, however, from 32-85% of this difference was attributable to the increased germination of *Betula papyrifera* under greenhouse conditions. Because of the sensitivity of some species to germination regime, extrapolation from greenhouse tests to potential weed populations in the field is unjustified.

Because the abundance of viable seed stored in the soil decreases with depth, the destruction of forest floor layers and the viable seeds stored therein will influence the composition of vegetation developing after disturbance. Not all sites can recover from the same degree of disturbance and hence clearing standard, or any other imposed disturbance, should be assigned on a site-by-site basis that recognizes site sensitivity.

HEAVY METAL LEVELS IN GRASSES AND LEGUMES GROWN
ON COPPER MINE TAILINGS

Coleen M. Hackinen

Graduate Student, Department of Soil Science
University of British Columbia

ABSTRACT

Samples of agronomic grasses and legumes grown on copper mine tailings under two surface amendment and fertilizer treatments were analyzed for Cu, Zn, Mn, Ni, Fe and Mo concentrations. These values were compared with Agriculture Canada diet recommendations for beef cattle. Foliar Mn, Ni and Fe levels were adequate to high and did not indicate a potential toxicity to beef cattle. Foliar Zn was deficient in some grass species. Cu/Mo ratios in all species were in the toxic range. Cu levels were high, therefore, the narrow ratio was attributed to excessive Mo. Mo in the grasses and legumes averaged 50 mg/kg and 235 mg/kg, respectively. These concentrations were several orders of magnitude above normal levels.

Tailing material was artificially weathered by leaching with 0.3 N acetic acid for seven weeks in a Soxhlet apparatus. Weathered and unweathered samples were analyzed for pH, 0.1 N HCl available Cu, Fe, Mn, Zn and Ni, acid ammonium oxalate extractable Mo, total elemental levels and mineralogical composition. As a result of leaching, the pH was reduced from 6.7 to 3.5. Available Cu, Fe, Mn and Zn declined considerably after weathering and small declines in available Mo were noted. No qualitative changes in mineralogy were detected on leaching. During leaching, three general elemental release patterns were observed. Initially, readily soluble salts and carbonates were removed, followed by the degradation of micas, pyroxenes, amphiboles and host ore minerals. The relatively inert minerals, such as, quartz, some aluminosilicates and oxyhydroxides of Fe and Al, represented the third group.

At present, the tailings are unsuitable as a forage production area for beef cattle as a result of toxic Cu/Mo ratios in the foliage. Based on chemical changes in the tailings after artificial weathering, however, it is probable that forage grown on this material will become less toxic over time.

THE RECLAMATION OF WASTE ROCK DUMPS AT
THE KITSALT MINESITE

W. A. Price

Graduate Student, Department of Soil Science
University of British Columbia

ABSTRACT

This paper presented information collected for the author's Ph.D. thesis. Evidence from field trials , a literature review and an offsite reconnaissance were used to develop a reclamation objective that can be achieved in the short term (about 10 years) and meets the site's end land use goals. Laboratory analysis and field trials have been used to test different components of the reclamation strategy. End dumping a veneer of quickly weathering rock appears to be the best method for quickly developing a rooting medium on the terrace slopes. Laboratory studies are being carried out to predict what happens to properties, such as chemical composition and particle size, as the raw mine wastes alter over time.

EXTRACTION AND MEASUREMENT OF OIL CONTENT
IN MINERAL FINES (SLUDGE)

P. Yeung and R. Johnson
Alberta Environmental Centre
Vegreville, Alberta

ABSTRACT

Oil production, processing and transport result in accidental spills in a wide range of environments. The choice of land reclamation procedures in these cases depends upon an analysis of oil content throughout the soil profile. Conventional methods for extracting and determining oil content in mineral and organic soils were reviewed and found unsatisfactory for measuring bitumen residues in mineral fines (sludge) resulting from oil sand processing. Common solvents, like toluene and methylene chloride, may not penetrate water-oil films associated with saturated fines. Pretreatment, by drying the sludge at 40°C, greatly improves the efficiency of oil extraction by methylene chloride. Drying an oil contaminated soil sample at higher temperature before oil extraction is not recommended due to loss of oil by volatilization. The chemical and physical properties of the oil-free sample are unaffected by the proposed extraction procedure, thus permitting further analytical measurements on previously contaminated samples.

INTRODUCTION

A method of extracting oil from soils and unweathered geological materials is needed to measure the level of contamination and to evaluate alternative reclamation procedures. Crude oil is soluble in a variety of organic solvents. Some organic solvents used in oil extraction methods for soils and water include methylene chloride (McGill and Rowell, 1980; Law, 1978), toluene (Patel, 1974), benzene, hexane and chloroform (Walker *et al.*, 1975), trichlorotrifluoroethane and carbon tetrachloride (Gruenfeld, 1973).

The most highly recommended method for oil extraction from soils now is probably methylene chloride (McGill and Rowell, 1980). However, the method needs modification for samples containing large amounts of water where oil-in-water emulsions can drastically reduce extraction efficiency. Furthermore, methylene chloride has low extraction efficiency in soils containing "untopped" or unaerated oil.

The reclamation of the solids portion (sludge) of tailings ponds associated with Alberta's oil sand industry requires a measurement of bitumen content and the elimination of residual bitumen from the sample to facilitate further analytical measurements. The existing methods cannot be used without modification because sludge contains large amounts of water (70-80% by weight) and a viscous, unaerated species of oil residue (Scott *et al.*, 1985).

This paper reports on the refinement of an oil extraction method which can be used on soils or unweathered geological materials containing any amount of moisture and oil in any state of oxidation. It compares the extraction efficiency of methylene chloride and toluene and defines a pretreatment suitable for a wide range of soil materials which does not change their inherent physical and chemical properties.

MATERIALS AND METHODS

Sludge and Soil

The oil-contaminated sludge used in this study is a by-product of oil production from oil sands. It is disposed of in huge tailings ponds near Ft. McMurray and consists of a thixotropic mixture of very fine mineral particles and process water (Table 1). There is approximately four percent residual bitumen in the sludge, left over from an incomplete extraction by the Clark hot water process. The residual bitumen represents lost product for the operating company and influences the choice of reclamation procedures of the unconsolidated sludge. The tailings pond environment is aqueous, highly alkaline and extremely sodic. The level of soluble salts is elevated but not extreme (Table 2).

The soil used in the evaluation of oil recovery procedures is the A horizon material from the Malmo series, Black Solod (Table 3). Oil-free samples of this surface soil were spiked with a

Table 1: Particle Sizes of Sludge

Particle size (μm)	% less than
88	99.2
44	95.0
22	88.5
11	75.2

Table 2: Properties of the Oil Sand Sludge

Sludge Properties	Measured values
Solids (%)	26
Water (%)	70
Bitumen (%)	4
pH	9.1
E.C. (mS/cm)	2.9
SO ₄ (ppm)	384
Cl ⁻ (ppm)	332
SAR	61

Table 3: Properties of Malmo Soil (A horizon)

Soil Properties	Measured values
pH	8.4
E.C. (mS/cm)	2.1
Saturation percentage	78.6
SAR	2.7
Sand (%)	27
Silt (%)	41
Clay (%)	32
Textural class	CL

known amount of "untopped" (unaerated) oil and extracted with both solvents. Selected chemical and physical properties of spiked and unspiked soil samples were measured to evaluate the effect of the solvent. All laboratory analyses, except as detailed in this paper, follow standard procedures (McKeague, 1978; Richards, 1954).

Measurement of Chemical and Physical Properties of Extracted Soils

One of the essential requirements of the proposed extraction method is that the properties of the extracted materials remain unaffected by the extraction procedure so that further analytical measurements can be carried out. Five treatments were used to evaluate the effects of solvent extraction on the properties of Malmo soils. Each treatment was replicated three times.

- T1 = oil-free soil extracted with toluene
- T2 = oil-free soil extracted with methylene chloride
- T3 = oil-affected soil extracted by toluene
- T4 = oil-affected soil extracted by methylene chloride
- T5 = no extraction (control)

Extractants

Toluene and methylene chloride are compared as oil extractants because of their ready availability, low toxicity and common use in analytical labs measuring oil content of soil or water (Patel, 1974; Hilpert *et al.*, 1978; Law, 1978; McGill and Rowell, 1980).

Sample Pretreatment

Often salt and acids are used as additives to organic solvents to improve extraction efficiency (Grunfeld, 1973). The development of a method for oil sand sludges precludes the use of additives because of sample contamination after extraction. Pretreatment by drying, as originally proposed by McGill and Rowell (1980) for organic soils only, seems a viable alternative. Malmo soil was wetted to field capacity (-33 kPa) and spiked with 5% (by dry weight) crude oil. The soil samples were then air-dried (22°C) for 7 days or oven-dried at 40°C or 105°C for 16 hours. Methylene chloride was used as the test extractant. Moist samples (-33 kPa), spiked with equal amounts of oil and not dried, were used as controls.

RESULTS AND DISCUSSION

Effect of Oil Extraction on Soil Properties

The investigation of the effect of different solvents on the properties of the extracted materials is a preliminary test to evaluate the effectiveness of the method for future oil extraction and measurement of mineral fines. Any change in properties of the tested materials by the extraction method will negate the usefulness of measuring the oil content.

Results of the tests indicate that neither the use of solvent

nor the addition and extraction of oil affects chemical properties of Malmo soil prepared in a saturated paste (Table 4). In addition, soil particle size analysis is not affected by solvent or oil addition and solvent extraction (Table 5). The results allow further determination of the choice of solvent.

Choice of Solvents

Methylene chloride and toluene were both tested as potential solvents of crude oil. Both were capable of recovering more than 75% of the crude oil added to a Malmo soil (Table 6). This is in agreement with results obtained in the experiment conducted by McGill and Rowell (1980) in which between 29 and 30% of untopped (unaerated) oil was not recovered by methylene chloride extraction from different soils. The slightly higher recovery efficiency of toluene was not statistically different than methylene chloride. However, methylene chloride requires only one-third the time of extraction of toluene. This is perhaps due to the lower boiling point of methylene chloride (40°C) than toluene (110°C). Walker *et al.* (1975) compared extraction efficiency of benzene, hexane and chloroform from oil-contaminated sediments, but 12-24 hours of extraction time was required. As a consequence of the large differences in extraction time, methylene chloride was used as the extractant of choice for further testing.

Effect of Pretreatment on Oil Extract Efficiency

In the case of soil, water content, drying temperature and drying time do not affect the relative oil extraction efficiency of methylene chloride. McGill and Rowell (1980) used methylene chloride to extract mineral soils and also found no differences in oil recovery whether the soil samples were moist (at field capacity) or air-dried. However, no attempt was made to oven-dry soil samples at 105°C. In our study, samples left to air-dry for seven days yielded the same oil recovery as soil samples which were oven-dried at 40°C or 105°C for less than one day.

Pretreatment of sludge samples is needed because extraction by conventional methods without modification were proven unsatisfactory (authors' unpublished results).

Sludge samples contain much higher clay content, large amounts of sodium and water, and differ greatly in their response to solvent extraction efficiency (Table 7). When no drying pretreatment is imposed (control) and moisture content equals 70% by weight, oil extraction efficiency is only 2% of that achieved by seven days of air drying. The sharp increase in extraction efficiency after drying can be explained by the elimination of the oil-in-water emulsions that cause extraction difficulty (McGill and Rowell, 1980).

The temperature of the drying treatment also affects the relative extraction efficiency in sludge. Sample drying at 40°C for 16 hours yields the same oil recovery as seven days of air drying. When sludge is dried at 105°C, however, extraction efficiency drops to 54% of the air-dried value. This is probably due to the loss of oil by volatilization.

Table 4: Chemical Properties of Soil With and Without Oil After Extraction With Two Solvents.

Treatment	pH [*]	E.C. (mS/cm)	Soluble Cations (meq/L)			
			Na	K	Ca	Mg
T	8.2	2.3	6.5	1.7	7.4	5.7
MC	8.3	2.3	6.6	1.7	7.4	5.6
OIL + T	8.5	2.4	7.3	1.8	7.4	5.8
OIL + MC	8.4	2.3	7.1	1.7	7.5	5.8
CONTROL	8.4	2.1	6.5	1.6	6.3	5.0

* Saturated paste

Values are averages of 3 replicates and are not statistically different.

T = toluene extraction
MC = methylene chloride extraction
OIL = oil-spiked
CONTROL = no extraction

Table 5: Soil Particle Size Analysis of Soils With and Without Oil After Extraction With Methylene Chloride.

Treatment	Sand (%)	Silt (%)	Clay (%)	Textural Class
T	31	38	31	CL
MC	31	37	32	CL
OIL + T	27	43	30	CL
OIL + MC	28	43	29	CL
CONTROL	27	41	32	CL

Values are averages of 3 replicates and are not statistically different.

T = toluene extraction
MC = methylene chloride extraction
OIL = oil-spiked
CONTROL = no extraction

Table 6: Oil Extraction Efficiency and Duration of Two Solvents in Malmo Soil.

Solvents	Oil recovery (%) [*]	Time (hr) required to complete extraction
Toluene	80	3
Methylene chloride	76	1

* Values are averages of 3 replicates and are not stastically different

Table 7: Effects of Drying at Various Temperatures on the Relative Extraction Efficiency of Methylene Chloride on Oil-spiked Malmo Soil and Mineral Fines (sludge).

Treatment	Relative Extraction Efficiency (%)	
	Malmo Soil	Sludge
Air dry for 7 days	100 a	100 a
Oven dry at 40°C for 16 hrs	99.8 a	98.9 a
Oven dry at 105°C for 16 hrs	95.3 a	54.2 b
Control* (no drying)	91.2 a	2.1 c

* Moisture content of Malmo soil and tailing sludge without drying equals 30% and 70% respectively.

For any column, values are statistically different if followed by different letters.

CONCLUSION

An oil extraction method for mineral fines using methylene chloride and pretreatment by mild oven drying at 40°C for 16 hours was developed. Results obtained in this study indicate that moisture in mineral fines significantly affects extraction efficiency. The amount of oil recovered was greatly reduced if sludge samples were extracted in a saturated condition. Oven drying at 105°C is not recommended due to decrease in extraction efficiency. Both chemical and physical properties of the extracted samples were not altered so that future characterization of the previously contaminated materials is possible.

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VISUAL IMPLICATIONS FOR RECLAMATION OF THE
CP DEBRIS FLOW TUNNELS IN YOHO NATIONAL PARK

Patrick A. Miller, Ph.D.

Landscape Architecture Program
University of British Columbia

ABSTRACT

This paper examines issues related to the visual impact of linear alterations to the landscape and the implications for reclamation. A visual impact study of Canadian Pacific Railroad's proposed debris flow tunnels in Yoho National Park provides a methodological example of how these issues can be addressed and the techniques which can be used in addressing them. The techniques demonstrated in this study include computer simulation and dominant line drawings. The recommendations for reclamation which result from this study are also discussed. Lastly, conclusions are drawn and recommendations are made for future studies of this nature.

CP RAIL ROGERS PASS PROJECT
RECLAMATION PROGRAM

David F. Polster
Polster Environmental Services
Revelstoke, B.C.

ABSTRACT

Work is currently underway on construction of a new 17.3 km surface grade and 16.5 km of new tunnels for westbound rail traffic on the CP Rail mainline between Golden and Revelstoke, B.C. Most of the work is being conducted in Glacier National Park. Detailed plans and contract specifications for the reclamation of approximately 150 ha of surface disturbance were developed with the objectives of controlling erosion, providing a permanent vegetation cover and reintegrating the disturbed lands with the surrounding terrain to reduce the visual impact of the project. The plans were based on results from two years of reclamation research and were submitted to Parks Canada and the Federal Environmental Assessment Panel established for the project. The plans were approved in a detailed agreement between CP Rail and Parks Canada. Stringent reclamation standards have been established for the project. Major reclamation work was initiated with construction in 1984 with an extensive program of soil salvage and use, seeding and woody shrub planting.

This paper details the planning process for environmental protection and reclamation on the project. Details of the implementation of the planned program, now in it's third year, are presented. The project provides a unique example of how engineering design and environmental design can be integrated to develop a program which is of benefit to all. Special reclamation techniques for stabilization and revegetation of steep slopes have been developed and are presented.

INTRODUCTION

The Rogers Pass Project is the largest single project undertaken by CP Rail since the completion of the transcontinental rail line in 1885. The project will complete the westbound grade reduction work which has been underway for the past 15 years. Adverse westbound grades will be reduced from the present 2.2 percent to 1 percent and an additional 34 km of double track will be constructed. This will allow CP Rail to significantly increase the number of trains moving through the Rogers Pass, thus increasing the capacity of this section of the line.

The project is being undertaken almost entirely within Glacier National Park. The sensitive nature of construction work within a National Park was recognized early in the development of the project and in February 1982, the Federal Minister of Environment requested the establishment of an Environmental Assessment Panel to review "...the environmental and related social impacts of the proposed Rogers Pass Development Project." (Environmental Assessment Panel, 1983). A detailed formal agreement was reached between Parks Canada and CP Rail which set forth the conditions under which the project would proceed. Specifications for the standards of environmental protection were included in the agreement as were standards for the reclamation of disturbances created by project implementation.

Major work on the project was initiated in the spring of 1984. Construction on all aspects of the project except the Shaughnessy tunnel which is the shorter of the two tunnels, was started at that time. By the end of the 1984 construction season, most of the clearing for the project facilities had been completed and a portion of the new grade had been built. The east and west heading of the Mount Macdonald, or long tunnel, were advanced to the point where construction at the faces could proceed over the winter. Reclamation work was conducted on the completed portions of the project and on sites where the temporary facilities would remain in place for the duration of the project.

Major reclamation work completed in 1984 included the landscaping of the construction camps which had been erected, seeding of completed portions of the cuts and fills along the surface route, and the planting of woody shrubs. The 1985 construction season saw the completion of the major bridges along the surface route, completion of most of the major earthworks along the new grade, and the initiation of work on the ventilation shaft for the Mount Macdonald tunnel. Again, reclamation work was scheduled to closely follow the completion of construction activities, and by the end of the season, a significant portion of the new surface grade had received reclamation treatments. This year will see the laying of track on 13 km of the surface grade, the hole through two of the tunnels, and completion of the overburden excavation for the ventilation shaft.

This paper presents an overview of the planning process which lead up to the initiation of construction. Details of the planning for minimizing and mitigating impacts on the environment

are presented. The second part of the paper outlines how the plans have been implemented with particular attention to the reclamation program as this is the major means of mitigating the adverse effects of the terrain disturbances.

PROGRAM PLANNING

Planning for the Rogers Pass Project was initiated in the mid 1970's when it became apparent that the existing capacity of the rail line would be reached. Significant increases in the need to transport bulk commodities such as wheat, coal, sulphur and potash to ports on the British Columbia coast were forecast at that time. Load forecasts were examined by the Canadian Transport Commission, and in March 1982, the Railway Transport Committee of the CTC approved the project. Concern for the environment, particularly in Glacier National Park, lead Parks Canada to request that the Minister of Environment establish an Environmental Assessment Panel to review the project and to make recommendations on how the project could proceed. Two sets of hearings were conducted by the panel, the first of which was held in the spring of 1982 and focussed on those aspects of the project which could be undertaken during the 1982 construction season. The panel also identified those aspects of the project for which more information was required. This information was to be collected during 1982 and early 1983 and a second set of hearings were scheduled for June, 1983.

In a preliminary report released in April, 1982, the panel recommended that construction could proceed at the east and west portals of the Mount Macdonald tunnel, and that an access road could be constructed along the surface route to facilitate collection of survey and geotechnical information needed for the detailed design of the new grade. Further information was required on the alternative locations for the ventilation shaft as the originally proposed site was found to represent an unacceptable intrusion in the National Park setting. Details of the reclamation of the new grade were also required. The panel found that the establishment of a work camp within the National Park would not seriously impair the quality of the Park as long as the camp was planned to harmonize with the Park setting. A system of committees was proposed to oversee the environmental and social aspects of the project and suitable personnel were to be hired.

A considerable amount of detailed information was collected and analysed during the period between the first and second set of hearings. A thorough survey of the new alignment was made. Cross sections of the terrain on either side of the new grade were surveyed and input into a computer. This allowed a variety of different alignments to be analysed with a minimum amount of tedious drafting work. Volumes of cut and fill could be calculated on the different alignments using the computer. In addition, perspectives of the grade from different viewing locations could be generated. A detailed visual analysis of the new grade was conducted from the perspective of visitors to Glacier National Park. Refinements to the alignment were made to minimize the visual impact of the grade. A significant number of retaining walls were incorporated in the design for the grade to

minimize the need for large cuts and fills. The landscape architect, reclamation planner, and design engineers worked together to produce a design for the new grade which minimized the impact of the project on the Park environment.

Cutting of an access trail along the surface route provided a means by which soil scientists and reclamation planners could assess the materials which would later be exposed in the cuts and fills. A detailed survey of the soil material was carried out to determine the revegetation potential of the different materials. This information was later incorporated into a plan for the salvage and utilization of the higher quality growth media. Selected locations along the access road and at the portals of the Mount Macdonald tunnel were seeded to test the revegetation potential of the different materials in the field. Table 1 shows the seed mixes used for the trials conducted in connection with the project. In addition to the trials conducted along the new surface grade, reclamation trials were established on the cuts adjacent to the bridge which had been constructed over Mountain Creek in 1977. This site is south facing, and is composed of glaciofluvial gravels, sands and silts. It was selected to represent the worst possible conditions for plant growth which could be expected along the new grade. Reclamation trial sites were selected to represent the widest possible range of conditions which might be experienced when the project was constructed. Sites ranged from shot rock at the East Portal to a boggy section along the new grade. Results of the trials were analyzed and incorporated in the plans for the reclamation of the new grade. The reclamation trials were designed as operational trials in that they sought to achieve some useful reclamation while at the same time providing an indication of the effectiveness of various species and techniques. Details of the reclamation trials were presented at the Ninth Annual British Columbia Mine Reclamation Symposium (Polster, 1985), and will not be repeated here.

Reclamation plans were developed as the major means of mitigating the adverse impacts of the project on the physical as well as the visual environment. The reclamation plans were formulated to meet the following objectives:

- * Revegetation of exposed erodible materials to minimize erosion and subsequent water quality degradation.
- * Amelioration of the visual impact of cuts and fills through the use of vegetation.
- * Establishment of a self-sustaining vegetation cover which is compatible with the naturally occurring vegetation in the area.
- * The use of native species which occur in the area, where this does not compromise the other objectives.

The reclamation plans were developed with a three phase approach to achieving these objectives. The emphasis of the first phase of the reclamation program is the development of a suitable substrate for vegetation growth. Detailed soil surveys were conducted and areas of available top dressing and areas requiring top dressing were delineated. The second phase of the reclamation program was designed to provide immediate erosion protection and

Table 1: 1982 Species Trials

GRASS AND LEGUME SPECIES

Alsike Clover
Sainfoin
Crown Vetch
Pubescent Wheatgrass
Tall Fescue
Birdsfoot Trefoil
Kentucky Bluegrass (Troy)
Canada Bluegrass (Rubens)

WOODY SPECIES PLANTED

Oregon Grape
Alder
Juniper
Kinnikinnick

SPRING TRIALS GRASS AND LEGUME SPECIES MIX

SPECIES	PERCENT BY WEIGHT
Creeping Red Fescue (Boreal)	8.74
Hard Fescue (Durar)	7.26
Kentucky Bluegrass (Troy)	0.98
Streambank Wheatgrass (Sodar)	22.12
Crested Wheatgrass (Fairway)	18.16
Orchardgrass (Chinook)	0.73
Timothy (Climax)	19.33
Alsike Clover (Aurora)	9.21
Alfalfa (Rambler)	7.17

FALL TRIALS GRASS AND LEGUME MIX

SPECIES	PERCENT BY WEIGHT
Creeping Red Fescue (Boreal)	13.20
Orchardgrass (Chinook)	8.00
Timothy (Climax)	36.50
Perennial Ryegrass (Tetraploid)	29.20
Alsike Clover (Aurora)	13.10

to aid in the amelioration of the visual impact of the cuts and fills. This phase consists of seeding the disturbed sites to a cover of grasses and legumes. Two seed mixes were formulated for this purpose. Table 2 shows the composition of these mixes. The third phase of the reclamation program is the establishment of a cover of native trees and shrubs similar to those found in the undisturbed sites adjacent to the construction areas. A survey of the native vegetation patterns along the grade was conducted and planting plans for trees and shrubs were formulated on the basis of this survey. The trees and shrubs to be planted on the disturbed sites are native to Glacier National Park. Specifications for the growth and supply of woody plants were developed with the intent of having sufficient stocks available. Seed and/or cuttings for these plants were collected in Glacier National Park or the surrounding area to ensure genetic compatibility with the undisturbed vegetation. The cover of trees and shrubs will form the final cover on the disturbed sites.

A program of reclamation maintenance was planned for in the reclamation plans. This program includes the touch-up seeding of sites where the initial seeding failed to catch, replanting if the density of the trees and shrubs fall below the established standards, and repair of slopes where slope stability problems appear. The program of maintenance will help to ensure that the final reclaimed areas are fully satisfactory.

Plans for the protection of the environment were formulated in concert with the detailed designs for the project. The protection of air and water quality as well as protection of vegetation adjacent to the construction areas were addressed in plans for the project. Preliminary plans were presented to the Environmental Assessment Panel while the more detailed plans were formulated and incorporated in the formal agreement between Parks Canada and CP Rail which was recommended by the Panel. Environmental standards were set for air and water quality and for noise associated with construction. Monitoring for compliance with the standards has been conducted by CP Rail on a regular basis, and by Parks Canada as spot checks.

Contract specifications were developed for all aspects of the work. The environmental protection standards were incorporated in the contract specifications. This meant that those who were going to be doing the actual work would be responsible to ensure that the standards for environmental protection were adhered to.

Standards for wastewater from the tunneling operations were included in the tunneling contracts, while specifications for the protection of air quality were included in the contracts for those contractors who would be operating concrete batch plants or had other operations which might impair air quality. The grading contractors were responsible for the control and protection of surface waters. In addition, development of suitable rooting media and final preparation of the surface of cuts and fills was made the responsibility of the grading contractors.

Contract specifications for the revegetation of the disturbances created in connection with the project were prepared.

Table 2: Grass and Legume Seed Mixes For Rogers Pass Project

SPECIES (Variety)	PERCENT BY SPECIES COMPOSITION	PERCENT BY WEIGHT
Dry Sites Mix:		
Creeping Red Fescue (Boreal)	15	10.32
Hard Fescue (Durar)	10	7.27
Kentucky Bluegrass (Troy)	5	1.14
Streambank Wheatgrass (Sodar)	10	27.20
Crested Wheatgrass (Fairway)	10	20.55
Orchardgrass (Chinook)	10	8.54
Timothy (Climax)	15	4.93
Alsike Clover (Aurora)	20	11.28
Alfalfa (Rambler)	5	8.77
Moist Sites Mix:		
Creeping Red Fescue (Boreal)	15	11.41
Kentucky Bluegrass (Troy)	5	1.26
Orchardgrass (Chinook)	10	9.44
Timothy (Climax)	15	5.45
Redtop	10	0.96
Slender Wheatgrass (Revenue)	10	29.95
Alsike Clover (Aurora)	20	12.45
Alfalfa (Rambler)	15	29.08

Again, the standards set in the agreement between Parks Canada and CP Rail were included in the specifications for the revegetation contract. The revegetation contract was set up so that there was a significant hold back of funds until the standards were reached. Standards for revegetation success are given in Table 3.

PROJECT IMPLEMENTATION

Major construction work on the Rogers Pass Project was initiated in the spring of 1984. Clearing was conducted over most of the surface route, and grading was initiated. Work at the two portals of the Mount Macdonald tunnel entailed the establishment of facilities for tunnel construction and tunneling. Water treatment facilities were established at both portals. Work at the ventilation shaft site during 1984 consisted of construction of an access road to the site and construction of a large retaining wall to hold the slope above the shaft site. Environmental protection measures such as the provision of stream diversions around bridge construction sites were implemented with the construction. Environmental protection during the 1984 season focussed primarily on the protection of watercourses, careful control of slash disposal fires, and protection of vegetation adjacent to the construction lands. Erosion control structures were installed at the end of the construction season in areas where erosion posed a threat. These consisted of temporary settling ponds, erosion bars, installation of culverts and ditches and the placement of straw bale sediment traps at strategic locations. No significant erosion of materials off the construction lands occurred during spring break-up in 1985.

The reclamation program was initiated with construction in the spring of 1984. Salvage of top dressing for later use on completed sites was the first priority. Top dressing salvage zones, as defined by the preconstruction soil survey, were marked in the field. In many cases it was possible to strip the soil materials from one area and place it on a completed area without having to rehandle the material. Soil stockpiles were developed at selected sites where needed. Top dressing was applied to cuts and fills where the native material was unsuitable for plant growth. In most cases materials were considered unsuitable because of the lack of nutrient and moisture retaining fine particles. Care was taken in the salvage of top dressing to include as much of the organic duff as possible. Soil stockpiles were seeded to a grass and legume cover if they were to remain in place long enough for the seeded cover to establish.

A portion of the grade had been completed by the fall of 1984, and a program of grass and legume seeding and shrub planting was conducted. A total of about 16 ha were seeded, including 8 ha along a powerline which had been built from Revelstoke to the project area. A total of 20,882 shrubs were planted in the fall of 1984 on the completed portions of the grade. Landscaping of the construction camps which had been established for the project was also undertaken in 1984. Sod was laid around the buildings and large trees were transplanted to the camp areas. The landscaping at the camps was conducted as part of the measures which were implemented to make the camps fit into the National

Table 3: Standards For Reclamation On The Rogers Pass Project

For Initial Cover:

- (1) Seeding and fertilizing shall result in a minimum of 10 healthy established plants per square yard (0.836 sq. meters) averaged over 100 square yards with an average canopy cover of not less than 80% including detritus, but excluding rock or other non-erosive surface, within any 10 yard by 10 yard area, except where by virtue of woody species growth the cover of seeded grasses and legumes is reduced and the cover provided by the woody species is equal to or greater than the amount of the reduction in grass and legume cover.
- (2) Performance tests will be conducted jointly by Parks Canada and CP Rail after three years of growth during which time no fertilizer has been applied.

For Woody Species Cover:

- (1) Planting of woody species shall result in a stocking of woody species which is not less than 75% of the stocking rate for the site shown on the approved reclamation plans.
- (2) Survival rate by percentage species composition shall not vary from the planted percentage species composition by more than 20%.
- (3) Growth rate of the stock shall not be less than 20% of the growth rate of the surrounding undisturbed native vegetation based on a measure such as leader growth extension.
- (4) The growth rate shall be measured after two consecutive growing seasons without fertilization.

Park setting.

The 1985 construction season saw the completion of a significant portion of the new grade. In many cases, the cuts and fills along the new grade were advanced to a point where reclamation activities could be conducted on the completed portions. Seeding with grasses and legumes was conducted in the early spring, late summer and late fall. A total of about 50 ha were seeded during the 1985 season. Planting of conifer trees was introduced to the program of woody species planting. A total of over 230,000 woody plants were established on the disturbed sites. Excessively dry, hot weather during the summer of 1985 resulted in the need to water the stock which had been planted. Provision for the watering of planted stock had been allowed for in the contract specifications for the revegetation contract. A hydroseeder was used to transport water to the sites being reclaimed. Watering was conducted during the early mornings and late evenings to avoid excessive evaporation during the days. A loss of about 3 percent of the stock which was planted in 1985 was attributed to the hot, dry weather. This loss would have been far greater had watering not been conducted.

Special reclamation techniques were applied to several sites. Live pole drains, where bundles of living cuttings of willow and cottonwood were buried in trenches at sites where seepage was resulting in the failure of the slopes, were established at several sites. The live pole drains provide a conduit for the moisture to flow from the slope without saturating the soil materials and causing slope failures. The system worked well, and by the end of the summer new shoots were apparent on the installed drains. Soil binding spray was used on several slopes to aid in the establishment of vegetation. The soil binding spray was used on two rock cuts where particularly weak rock was encountered. The spray held the fine rock particles and seed in place and allowed the seed to germinate and grow without being washed from the slope. The rock cuts were established at a slope of about 51 degrees. Establishment of vegetation on these slopes will aid in the amelioration of the negative visual impacts of these cuts as well as helping to hold the rock in place. Soil binding spray was also used on constructed slopes of the ventilation shaft access road. These slopes were constructed of a fine textured sand which proved to be highly erosive. The soil binding spray held the soil and seed in place and allowed a sod to form. Living cuttings were driven into the slope in the fall to help to hold the sod in place. These are growing and will form a dense brush cover on the slope. Further use of live pole drains, brush layers and soil binding sprays was made this spring. Several areas of instability were treated with live pole drains, and brush layers, and additional rock cuts were seeded using the soil binding spray.

The special reclamation techniques used on the Rogers Pass Project have been developed to compliment the planned program of reclamation for the project. The use of soil binding sprays and various bioengineering techniques are effective at providing a vegetation cover on particularly difficult sites. The effectiveness of these measures depends on the appropriate use of

the system. These special techniques are expensive compared to standard reclamation methods but, compared to engineering solutions, the costs are significantly less. Acceptance of these special techniques will ensure their further use in the future.

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B.C. HYDRO ROAD EROSION CONTROL AND
RIGHT OF WAY REVEGETATION PROGRAMS

Ian Wright, A.Sc.T.

Former R/W Design Technologist with
B.C. Hydro Transmission Projects Division

ABSTRACT

Access road erosion control and right of way revegetation became an integral part of the construction phase for new 500 kV, 230 kV and 138 kV transmission lines in 1981. All activities related to road erosion control, right of way revegetation and site specific revegetation and stabilization is collectively called restoration.

The purpose of the road erosion control program developed during the construction phase was to provide a stable road system usable for regular patrol, maintenance and emergency use.

The road erosion control program included a number of treatments such as ditching, ditching and crowning, and gravelling, to establish a stable road grade. The most widely used method to control road erosion is water bar installation.

Three types of water bar installations are used:

- (1) Standard waterbars: Built of local soil materials;
- (2) Gravelled waterbars: A gravel or rock lined water bar installed in highly erodible soils such as silts and sand;
- (3) Cross drain: Installed on those roads no longer required or to prevent vehicular traffic.

General quantities and costs for the above installations for the Peace River region and the lower British Columbia coast are:

(1) Peace River region:

Water bar installation cost	\$ 169/wb
Water bar quantities	
- silty soils	7 wb/km
- gravelly clay soils	3 wb/km

(2) Lower Coast:

Water bar and cross drain installation cost	\$ 178/wb
Water bar quantities	
- glacial tills	6 wb/km

Right of way revegetation is an established practice following right of way clearing. Rights of way are seeded as soon as possible following clearing. Seeding is also undertaken:

- to meet commitments of outside agencies or other resource users;
- good corporate citizen;
- as a vegetation management tool to inhibit brush invasion.

All broad right of way seeding undertaken in the period of 1981 - 1985 was by helicopter. Helicopter seeding provided better seed

mix application control and contractor supervision than fixed wing aircraft. Helicopter seeding costs ranged from \$30 - \$40 per hectare for applications of 25 kg/ha.

Seed mixes were compiled using a variety of sources. Typically, biophysical information from government ministries and B.C. Hydro route location studies identified sensitive areas and predominant vegetation associations, native and agronomic grass and legume species summaries and local expertise such as range specialists were also consulted to compile seed mixes that would provide fast establishing and vigorous coverage as quickly as possible consistent with right of way management objectives.

Site specific treatments and costs undertaken and incurred from 1981 - 1985 are:

- (1) Hydroseeding: \$1700 - \$2000/hectare;
- (2) Harrow and broadcast seeding: \$500/hectare;
- (3) Native shrub planting: \$2.50/shrub (An all found cost including cost of stock, design time, reports, labour and supervision);
- (4) Helicopter hydroseeding: \$1700 - \$2000/hectare.

URBAN RECLAMATION PLAN FOR THE
B.C. SKYTRAIN

David Easton, BCSLA, CSLA
Landscape Coordinator
B.C. Transit

and

Jonathan Losee, BCSLA, ASLA, CLRA
Pavelek and Associates
Landscape Architects Ltd.

ABSTRACT

The first phase of B.C. Transit's SkyTrain is a 19 kilometer long concrete guideway that shuttles passenger loaded automated trains from Vancouver's waterfront, through Burnaby, to downtown New Westminster, B.C. The SkyTrain is a heavily used system, having a daily passenger use of over 30,000.

Because of it's high visability, both from the SkyTrain and of the guideway from below, reclamation of the disturbed landscape was a high priority. All phases of construction of the pylons, guideway and stations required continuous access for heavy construction equipment. This created a 20 - 30 meter wide swath of disturbed and compacted earth passing through a mix of sensitive urban landscapes. Initial plans for restoration called for a "natural systems" approach to revegetation based on variables such as slope, aspect, soils, surface condition, location, and anticipated management of the final landscape. The result of this phase of reclamation was to be a cost-effective method of successfully revegetating the disturbed SkyTrain corridor. The first stage of hydroseeding was tendered and implemented in the fall of 1984.

In the spring of 1985, the site reclamation package changed to include extensive landscaping plus construction of jogging and cycling pathways. Lead by the Honorable Grace McCarthy, Minister Responsible for SkyTrain, the Provincial Government spearheaded an ambitious campaign in partnership with the Federal Government to obtain private and corporate donations to create the B.C. Parkway. A Master Plan designated a pair of linear pathways that linked the Parkway with existing parks within Vancouver, Burnaby, and New Westminster. Design Guidelines and Standards specified details and conformed to municipal standards for design and construction including clearances, utilities, grading and drainage, path layout, landscape standards, lighting and irrigation. As increased funding for the project became available, the scope of reclamation changed from the hydroseeding and rooted cutting program originally planned to an extensive urban landscape installation. Work began in the spring of 1985. B.C. Parkway was officially opened in July, 1986.

INTRODUCTION

The construction of B.C. Transit's Advanced Light Rapid Transit system, now called SkyTrain, created a 20 - 30 meter wide swath of disturbed and compacted earth 19 kilometers long passing through three municipalities and a series of urban, suburban, industrial, and residential landscapes. Because of its impact upon the cities, and its high visibility, sensitive land reclamation was a high priority.

Limited funding for site restoration required that an economic "Natural Systems" approach to site revegetation was developed. This method was carefully researched and documented for construction. The methods and prescriptions for revegetation will be further described herein.

By the spring of 1985, after 90% of the guideway construction was completed, the Honorable Grace McCarthy, Provincial Minister responsible for Rapid Transit, spearheaded a campaign to use the SkyTrain construction as a springboard for developing a linear park system. Supported by the Federal Government, and a massive campaign to solicit and obtain private and corporate donations, B.C. Parkway was realized. Funding became available to construct the parkway using traditional landscape techniques.

SITE DESCRIPTION

Location

The first phase of The SkyTrain is a nineteen kilometer long link between the waterfront of Vancouver, B.C. with downtown New Westminster, passing through Burnaby, B.C. (Figure 1)

Site Conditions

Consultation did not begin until after construction of the guideway was well under way. Construction had resulted in severe disturbance of the vegetation and native soils along the route. The soils along the guideway were not assessed for their suitability as topsoil prior to the commencement of construction. Suitable topsoil materials had generally been mixed with the subsoil, removed from the site or buried. As well, very gravelly sandy subsoil material and dredge sands had been imported and used for foundation and backfill material around the columns.

Soils

The native soils were developed on fine textured glaciomarine and moderately coarse and very coarse textured glacial till and fluvioglacial deposits. The dominant soils were derived from the moderately coarse and very coarse textured glacial deposits.

The remaining surface materials along the guideway were very infertile as a result of the construction activities. The organically enriched surface horizon of a major portion of native soils had been destroyed as a result of removal, burial or mixing

Figure 1



with the subsoil. Fill materials and subsoils were then exposed. They had generally less than 2% organic matter as opposed to 10%, an amount more typical of native topsoils. The available soil nitrogen was also very low, averaging 0.04% in comparison to the desirable level of 0.4%. The soils also had low amounts of potassium, phosphorus and magnesium. Generally, the soils were slightly acid (pH 6.1-6.5) and would not require liming with the exception of some areas east of Central Park in Burnaby, which were alkaline having a pH of 7.0-8.8.

The physical properties of the soils had been severely disturbed. The use of heavy equipment had frequently resulted in compaction, deep rutting and loss of soil structure around the columns and along the guideway where it was used as a temporary road during construction of the rail system. As well, excavation had resulted in the exposure of naturally compacted subsoils on cutbanks.

Although there was some variability in the texture, the materials occurring along the guideway could be divided into three major groups: The moderately coarse textured glacial deposits, the very coarse textured glacial deposits and dredge sands brought in as fill.

Slopes

Construction had resulted not only in burial or degradation of the more fertile components of the native soils, but also in the exposure of natural, steep slopes which were sensitive to erosion and which were devoid of vegetation. As well, steep slopes were created and often consisted of material which had a low suitability for plant establishment. Many of the slopes were engineered to a 1 1/2:1 to 2:1 slope and by the time of the study were showing signs of surface erosion. Because a majority of the on-grade guideway was on either a cut or fill situation, on an east-west axis, aspects of the slopes were generally north or south facing.

Vegetation

Much of the natural vegetation had been destroyed during construction. However, there were many areas where remnant native vegetation existed, and would eventually encroach onto low maintenance areas. The common vegetation types included: trailing blackberry, broom, horsetail, alder, salmonberry, salal, and buttercup.

RECLAMATION

The SkyTrain passes through a geography rich with a variety of land uses, ranging from downtown urban centres to outlying parks and forested areas. The natural systems approach to reclamation could not easily address the wide range of cultural, political and financial attitudes towards the landscape, except by altering seed mixes or changing the type of plant material used. However, with the final implementation of the B.C. Parkway, significant and sophisticated landscape designs were installed to

address these items. In outlying areas, away from residential or urban properties, simpler hydroseeding techniques were implemented, especially for slope stabilization and erosion control.

The intent of the natural systems program was to assess the disturbed site with respect to the exposed surface condition, slope, aspect, and future management techniques, and assign a specific site treatment to the site. The three site treatments were:

- (1) Surface treatment
 - a. scarify surface 5 cm of soil
 - b. cultivate upper 15 cm of soil
 - c. deep plough upper 30 cm of soil
 - d. straw mulching, tacked to the surface
- (2) Soil amendment
 - a. incorporate 5-7 cm of peat or manure
 - b. cover surface with 7+ cm topsoil
- (3) Revegetation treatment
 - a. hydroseed - mixture contains seed, fertilizer, 500 kg/ha woodfiber mulch
 - b. hydroseed - mixture contains seed, fertilizer, 1000 kg/ha woodfiber mulch, soil binder
 - c. hydroseed - mixture contains seed, fertilizer, 1500 kg/ha woodfiber mulch
 - d. surface cultivation - dry seeding

The resulting Prescriptions for Revegetation which assigned either one or a combination of the three site treatments to a particular site condition were used to prepare a master plan for reclamation for the entire site. Specific site treatments were assigned based upon cost for installation, anticipated success of ground cover, both immediate and long term, and aesthetics, or the look and function of the finished product.

Hydroseeding

In the fall of 1984, the first hydroseeding contract was tendered. The entire guideway route was seeded with the intent being to provide a quick vegetative cover to protect the slopes from the winter rains. The following mix design was implemented:

Seed Mixture A: used for all slopes, industrial sites, and sites where little maintenance would occur.

25 % Orchard Grass	<i>Dactylis glomerata</i>
20 % Italian Ryegrass	<i>Lolium multiflorum</i>
20 % White Dutch Clover	<i>Trifolium repens</i>
10 % Timothy Grass	<i>Phleum pratense</i>
10 % Canadian Bluegrass	<i>Poa compressa</i>
10 % Creeping Red Fescue	<i>Festuca rubra</i>
5 % Lupine	<i>Lupinus polyphyllus</i>

Seed Mixture B: used in park settings where regular maintenance

practices would be used, i.e. mowing, watering, and fertilizing.

35 % Canadian Bluegrass	<i>Poa compressa</i>
25 % Creeping Red Fescue	<i>Festuca rubra</i>
20 % White Dutch Clover	<i>Trifolium repens</i>
15 % Italian Ryegrass	<i>Lolium multiflorum</i>
5 % Perennial Ryegrass	<i>Lolium perenne</i>

Seed Mixture C: used on slopes and sites with high visibility. This red, white, yellow and blue wildflower mix was added to mix A at a 70% of mix A to 30% mix C ratio.

20 % Alaska Daisy	<i>Chrysanthemum maximum</i> "Alaska"
20 % Blackeyed Susan	<i>Coreopsis grandiflora</i> "Sunburst"
20 % Blue flax	<i>Linum perenne</i>
20 % Lupine	<i>Lupinus polyphyllus</i>
10 % Iceland poppy	<i>Papaver nudicaule</i>
10 % Allegro poppy	<i>Papaver</i> "Allegro"

In all cases, seed mix was applied at 140 kg/ha; a 19-19-19 fertilizer having 50% s.c.u. was applied at 215 kg/ha; epsom salts applied at 145 kg/ha; wood cellulose fibre was applied at 1500 kg/ha; an erosion control agent "J-Tac" by Rectamare Company was used at 28 kg/ha on all slopes between 3:1 and 2:1; slopes steeper than 2:1 had an application of Deci 162 by Denca Construction Specialties Ltd. The Deci 162 was also spot applied on specific disturbed areas where the extra soil stabilization benefits were required.

B.C. PARKWAY

B.C. Parkway developed from the desire to do more with the SkyTrain right-of-way than simply restore it to its original conditions. The unique situation of a twenty to thirty meter wide continuous corridor bisecting the Greater Vancouver area from False Creek in Vancouver, to the Fraser River in New Westminster offered a great potential for recreational development.

Twin systems of pedestrian/jogging paths and bicycling trails were planned parallel and adjacent to the SkyTrain, sharing the right-of-way with B.C. Hydro rail tracks, high pressure gas lines, water mains and underground electrical transmission lines. Landscaping was designed to complement these recreational paths, varying in character depending upon surrounding conditions. Urban neighbourhoods dictated a formal and elaborate landscaping treatment while rural or suburban areas needed a more naturalistic response. Varied settings included industrial areas, residential districts, city parks, arterial boulevards, sanitary landfill sites, and forested areas.

Nineteen kilometers of the two paths stretched through three municipalities. To facilitate this development beyond the original two million dollar restoration budget, a Canada Manpower program was set in place to provide labourers for each municipal sector within the Parkway, and engineering supervisory staff was provided by the municipalities to implement designs for the B.C. Parkway. In addition to this federal grant of 1.5 million dollars

for labour, corporate sponsors, private individuals, cultural communities and service groups donated approximately 2 million dollars to provide the total of 5.5 million dollars to complete the project. Major donors were designated on site by signs or plaques and special mention was given to Molsons for donating the funds for the John Molsons' jogging path, and 7-11 for donating funds for the 7-11 bicycle trail.

The construction of paths was based on local municipal standards with layout and design for bicycle trails conforming to B.C. Bicycling Association requests and American Association of State Highway and Transportation Official standards. To define separate functions and discourage bicyclists from using the jogging/pedestrian paths, compacted limestone screenings to a depth of 50 mm were installed over a compacted road base and edged with double, pressure-treated 12 mm x 100 mm wooden edgers. The fine screenings provided a good resilient surface for running and walking. Bicycle trails were constructed of 50 mm hot rolled asphalt 3 meters wide over a compacted road base. Street inter-sections and special areas were marked with coloured, interlocking pavers and white traffic barrier posts. Signs designate path uses and flag areas of interest or potential hazard.

Standards for landscape restoration varied with the B.C. Parkway context. In general, urban and suburban area's standards required scarification and importation of 75 mm topsoil for lawns and 300 mm for shrub beds. Wilder areas and steep slopes were cleaned, raked and hydroseeded as previously described. Some areas received a mixture of 80% low growing white clover and 20% wild flower seed mix and met with great public acceptance.

Plant materials were generally specified in standard nursery sizes and supplied by local growers. Varieties were selected based on site conditions and microclimate as well as appearance. Trees were selected in both nursery sizes and larger, specimen sizes, and all were supplied locally. Mature trees required heavy equipment as well as extensive labour for installation but provided instant visual impact and greater resistance to vandalism and adverse site conditions.

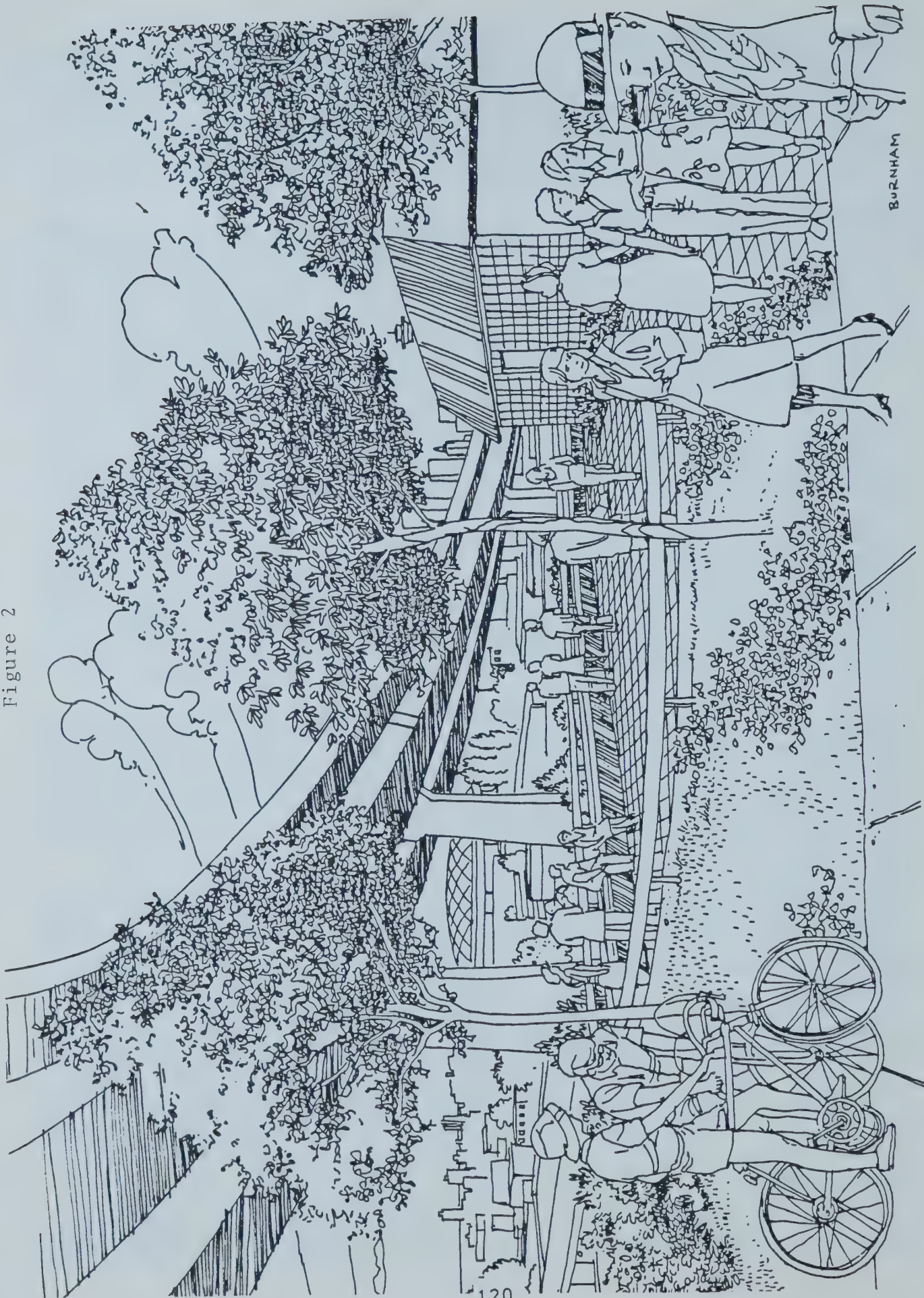
As a finishing touch, over two hundred thousand tulip bulbs were planted in the fall of 1985 to bloom for the spring opening. These were followed by the planting of fifty thousand annuals to provide summer colour and interest in key locations.

The B.C. Parkway Committee, a thirty person board of volunteers representing municipalities and local leaders of industry and commerce, approached sponsors for designated special projects within the context of the B.C. Parkway. As a result, plazas, seating areas, playgrounds, drinking fountains, special planting and other features completed the linear park system (Figure 2).

CONCLUSION

The evolution of the B.C. SkyTrain corridor from a simply restored right-of-way to a linear park complete with jogging and

Figure 2



cycling paths, special features and landscaping has fulfilled the potential for a successful urban reclamation project. By using the informed direction of consultants, the resultant B.C. Parkway is a celebration of what community efforts can achieve.

ACKNOWLEDGEMENTS

- * Teresa Watts, Manager, B.C. Parkway
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- * Talisman Land Resource Consultants

LANDFILL AREAS AND ITS VEGETATION

Dirk Oostindie

Parks Superintendent
District of North Vancouver

Oscar Singing "I Love Trash" From Sesame Street

O.K., O.K., I've waited long enough and now the time has come.
Oscar, what are you doing?

What does it look like I'm doing, Bob?

Well, it looks like you're making a mess.

I'm getting ready to sing my song, so I'm throwing out all my trash onto the sidewalk. Isn't it beautiful?!

Well, I wouldn't say it is exactly beautiful, Oscar.

Well I would. Just look at it all.

What a beautiful junky mess of rotten, rusty, maingy, musty, crummy beautiful trash.

"Oh, I love trash - anything dirty, or dingy, or dusty, anything ragged or rotten or rusty. Yes, I love trash. If you really want to see something trashy, look at this - I have here a sneaker that's tattered and worn. It is all full of holes and the laces are torn. A gift from my mother the day I was born. I love it because it is trash. Oh, I love trash - anything dirty, or dingy, or dusty, Anything ragged or rotten or rusty. Yes, I love trash."

"The American dream is alive and well. Garbage is the great equalizer" and as Oscar sings in Sesame Street's "I Love Trash", it is nice to know that some of us enjoy it.

With this lovely introduction on garbage, let us turn to the more mundane matters, and that is the conversion of landfill sites to active and passive recreation.

Some of the questions often raised are:

1. What species will thrive on completed landfill sites?
2. Are there any techniques available which will help in attempting to establish a vegetation cover over a completed landfill site?
3. What is the nature of the toxic effect of landfill gas on vegetation?

A number of reports are written, mostly coming from the Eastern U.S.A., Britain, West Germany and Holland. Out of those reports we can make some conclusions, although the plant material may be very foreign to the Pacific coast, the principles are still very much the same regarding gas, type of tree material, grasses, etc.

Recommendations concerning site preparation, tree planting and cultural practices to maintain plant material on landfill sites will depend upon the proposed use of the landfill, the composition and preparation of the refuse, the kinds of soil available and the characteristics of the site. Choice of plant material depends upon use, not so much aesthetic reasons. It should be chosen primarily for survival first as overall growth

will keep the cost down. Refuse composition and preparation is a determining factor as the gas may contribute significantly to deterioration and death of any plant material.

From the many observations made, either by research or non-scientific observations, we have some facts which most of us can use when preparing a landfill for landscaping:

1. When planting shrubs or trees, never plant mature plant material as the deep roots will meet oxygen poor air as the methane bacteria will take away the oxygen. The roots of mature plant material are less flexible and are already located deeper on planting.
2. Try to landscape with plant material that has a slow growth and in their natural state is in oxygen poor conditions, such as plants that thrive in wet, marshy conditions.
3. Start with young plant material. The plants, when meeting oxygen poor layers, will try to recover on shallower layers.
4. Another factor to consider is selecting tree species which are relatively small at maturity, when we don't have much soil. This risk is diminished when we have soil covers of 1 meter and more.
5. Irrigation is important especially the first two or three years. Most landfill operations don't have much soil, as such, not much moisture is available. Also the root systems are mostly located close to the surface and lack established capillary pore space. However, to install an inground irrigation system is not recommended, as due to settlements, the underground pipes will break or split. Mulching with wood chips, bark, sawdust, or grass clippings can help in controlling evapotranspiration by reducing soil temperatures, weed growth and evaporation from the soil surface.
6. One report recommends continuous extraction of the gas by an induced exhaust system, to reduce the quantity and pressure of the landfill gas generated in the refuse. Another way to protect the root system is when we prepare and cover the refuse. A barrier of clay or similar material will act as an impermeable layer. A layer like this is more flexible than plastic or others. This should keep the gas away from the cover soil, which will be placed over the barrier. A good example of this I saw at the St. John's landfill site.
7. Soil structure can also be improved by establishing a grass or ground cover with tall fescues, rye grass, crown vetch, lupine and clover. The latter for the nitrogen producing bacteria. This includes alder trees.

Last year, we planted several plant species, *Salix* - willows, *Betula* - birch, rose varieties, *Sorbus aucuparia* - mountain ash, mahonia, *Symphoricarpos* - snowberry, *Cornus* - dogwood, and a few more. The survival rate is poor - 8 to 10%.

Pine trees planted two years ago do very well, however, which perhaps can be attributed to their drought resistance. As such, this test planting did not tell us that much as we had no water control and the summer of 1985 was extremely hot. We have successful growth of young alder and cottonwood, kale, clover and lupine, and of course the grasses.

Seeding application was done by hydroseeding using mulch (wood fibre cellulose) and tackifier. With the assistance of staff members from Terrasol, we have now established a mixture that seems to do very well.

A batch of 1,100 lbs. would consist of the following:

- 20% Derby Perennial Ryegrass
- 30% Sydsport Kentucky Bluegrass
- 30% Dawson Fescue
- 20% Dwarf White Dutch Clover

We would be adding:

Crown Vetch	10 lbs.
Hairy Vetch	"
1,00 Headed Kale	"
Narrow Stem Kale	"
Wildflower Mix	5 lbs.
Dwarf White Clover Multicoated	50 lbs.
Russel's Perennial Lupines	15 lbs.

OIL AND GAS DRILLING WASTE MANAGEMENT CONSIDERATIONS
BY PUBLIC LANDS DIVISION STAFF
DEPARTMENT OF FORESTRY,
LANDS AND WILDLIFE
IN ALBERTA

David A. Lloyd, P.Ag. .

Reclamation Co-ordinator, Public Lands Division
Dept. of Forestry, Lands and Wildlife, Alberta

ABSTRACT

In 1975, the Energy Resources Conservation Board, the Department of Environment, the Department of Energy and Natural Resources and industry developed drilling fluid disposal guidelines to provide some control over fluid disposal operations. Public Lands Division assumed management control of these guidelines in September 1983. Because the drilling wastes are toxic and because not much is known about how to properly dispose of the fluids and solids, several steps were taken to help resolve the complex drilling waste disposal problem. Sump contents were analyzed using standard soil analysis procedures. Some major detrimental components evidenced were high sodium, high chlorides, high pH and high potassium. Common soil parameters were then noted to help discern disposal options. Burial and deep trenching are being discouraged on open rangeland or agricultural soils. Proper berming of wellsites is being stressed. Surface disposal through on or off lease disposal of treated fluids (where required) and land spreading the solid portion is now encouraged where land is suitable. A consultant was hired to provide an interim disposal manual for use by government field staff. Ongoing site evaluations and field trials should help lead to more suitable and environmentally acceptable drilling waste disposal practices on public lands in Alberta.

INTRODUCTION

Since oil and gas exploration began in Alberta, over 100,000 wells have been drilled. The wells range in depth from several hundred feet to over 20,000 feet. The larger oil discoveries such as Turner Valley and Leduc have resulted in closer well spacing with often a well for every quarter section. The foothills and mountain regions have the deeper wells and the southeast plains regions have the shallower wells. More recently, heavy oil development in the Lloydminster, Cold Lake and Peace River regions have caused such concentrated well spacing that pad systems from five to 20 wells per two to four acre-sized pads are being drilled. The numerous wells drilled in the past and the many wells to be drilled in the future plus the increasing complexity of drilling waste components have all heightened the concern about how to safely dispose of all drilling wastes produced.

DRILLING WASTES

For purposes of this discussion drilling wastes are those components that remain in a drilling waste sump pit after a well has been drilled. The wastes are composed of many varied substances and no two pits are likely to contain the same constituents.

The wastes generally comprise the following components:

- bentonite (sodium montmorillonite)
- water
- salt
- crude oil
- other additives such as:
 - sodium acid pyrophosphate
 - bicarb of soda
 - aluminum silicate
 - carboxymethyl cellulose
 - guar gum
 - CaSO_4
 - starch
- cuttings from the hole

A major problem that can occur with drilling waste sumps is that the rig crews can view the sump as a garbage pit and dump in the following:

- scrap iron, drums, cans
- drilling mud sacks
- casing protectors
- engine oil
- rig detergent or rig wash

Because sumps contain a complex mixture of liquids, solids, organic and inorganic compounds, the components may remain inert, or more likely interact synergistically or antagonistically (Shaw, 1986, personal communication). Such degree of known reaction and component complexity makes treatment difficult and potential

detrimental environment impact very probable.

The 1985 Energy Resources Conservation Board (ERCB) Interim Report No. 1 titled "Determination of Toxicity of Sump Fluids" illustrates the concern relating to sump fluid toxicity. In 1983-84, 10,929 wells were spudded. Sump fluids were tested for 574 of these wells and 344, or 60%, of the wells were found to be toxic. The toxicity parameter used was the 96 hour Trout Test or the Microtox Test which uses bacterial fluorescence.

REGULATORY CONSIDERATIONS

The Public Lands Division is one of two divisions in the Department of Forestry Lands and Wildlife in the Province of Alberta responsible for managing all the Crown-owned lands. Public Lands Division manages those lands found within the non-forested, more settled areas of the province. The Alberta Forest Service, the other division, manages all Crown land within the forested area of the province. Generally, outside of water and air, these two divisions are responsible for safeguarding the land surface against environmental damage. These two divisions are responsible for enforcing the regulations pertaining to sump waste disposal on Crown lands.

Interim Directive ID-OG 75-2

Exploratory drilling, production and most wellsite activities are regulated by a government-designated body, the ERCB. The board is also responsible for controlling pollution and ensuring environmental conservation in the exploration for, processing, development and transportation of the energy resources. In the early 1970's the ERCB realized that disposal standards were necessary to deal with toxic drilling wastes. Working with industry and the two main government departments, Alberta Forestry (now Department of Forestry, Lands and Wildlife) and Alberta Environment, in 1975 the ERCB developed interim guidelines called Interim Directive ID-OG 75-2 (75-2). These guidelines were issued in August 1975 (Appendix I) and pertained to the surface disposal of drilling fluids (not the solids component). Public Lands Division assumed management control of the sump fluid guidelines in September, 1983.

The 75-2 guidelines have two features worth highlighting. The first concerns on-lease sump fluid disposal. Here the fluids must be contained to the lease, with the main criteria being that the fluids must usually be less than 6,000 barrels in volume. The lease must be 100 m from the normal high water mark of a water body. The second feature, off-lease sump fluid disposal, is acceptable when the following criteria are met:

- a) Chloride content: 1,000 mg/L maximum
- b) Sulphate content: 2,000 mg/L maximum
- c) Total Dissolved Solids: 4,000 mg/L maximum
- d) pH must be between 5.5 and 8.5
- e) Trout survival test: three trout fingerlings (four to 10 cm must survive 96 hours in the treated fluid)

Subsurface Disposal

In 1981, the ERCB brought out a directive concerning the subsurface disposal of drilling fluids (Appendix II). Fluids may be disposed to unsuccessful drilled holes or to any well designated by the ERCB. The disposal zone must be at a depth greater than 600 m to protect potable water sources. Formation water in the disposal zone must not have a total dissolved solids content of less than 20,000 ppm, again to protect potable water sources.

KCl Disposal

In 1982, the Department of Energy and Natural Resources issued an Information Letter requesting that any company utilizing KCl drilling muds on Crown lands must submit a disposal plan which requires department approval before lease construction (Appendix III). The letter was issued because of KCl toxicity problems which could harm plant and animal life.

Acre Spread Rate

Because of the toxicity that sodium and potassium pose to animal life and the ion and salt effects on vegetation, a control measure to handle salt muds was proposed by the chief chemist, Mr. D. Shaw, of the ERCB. Using barley and conifer seedlings grown in trays containing a soil mix with a starting conductivity of 0.6 dS/m, Mr. Shaw washed the seedlings in several NaCl baths at different concentrations to determine salt tolerance.

Eventually Mr. Shaw determined a figure of 450 kg of chloride that could be safely spread on a hectare of soil without damaging a seedling. Thus Mr. Shaw determined a calculation to estimate the number of hectares required to spread chloride salts based on:

- chloride ion concentration in ppm
- a barrel of fluid (159.11 L) weighing 145.45 kg
- the number of barrels for disposal
- a spread rate of 450 kg Cl⁻ ion/ha

The equation is thus:

$$\text{Area required} = \frac{[\text{Cl}^-] \text{ ppm} \times 159.0 \text{ kg/bbl} \times \text{no. of bbls}}{450 \text{ kg Cl}^-/\text{ha} \times 10^6 \text{ (to cancel ppm)}}$$

Thus one could spread 1,000 barrels at 3,000 ppm over one hectare. The above spread rate can probably be adjusted higher on lighter textured soils depending on sodicity of the muds and receiving soils, and if calcium amendments are used.

INHERENT TOXIC PROBLEMS

At least two main inherent considerations with drilling wastes that impute toxicity problems must be considered in disposal situations. The first is the chemical makeup of the waste. The second aspect is the physical makeup of the actual

sump material.

Chemical Considerations

Chemically, drilling wastes pose four major environmental concerns. The first, and not necessarily most hazardous concern, is the inorganic or salt components. In Alberta, with the larger heavy oil developments occurring in Lloydminster, Cold Lake and the Peace River regions, large quantities of drilling wastes are going to be produced over the next several decades. Most of the drilling wastes will be salt based with the salts being predominantly sodium and potassium chlorides. Smaller amounts of potassium sulphate, magnesium chloride and sodium sulphate will also be present in these mud and fluid components. Several million kilograms of salt will be produced in these muds by the time drilling activities start to decline. The major concern is how the salts will affect soils, vegetation and groundwater. About 220,000 ha of arable land are being salinized each year in Western Canada (P.F.R.A., 1983). Though some of the salinization is due to agricultural practices, the concern remains that any additional salt buildup at the land surface is not favourable and should be avoided where possible.

The second chemical concern is the problem of increased concentrations of sump contents. Because the 75-2 guidelines state that sumps under 6,000 barrels may be spread on the lease, if the contents can be contained to the lease area, industry has made an effort to reduce the fluid content of the sumps. However, the reduced liquid component only increases concentrations of salt and organics because what could have been an 8,000 to 10,000 barrel sump often ends up being a sump smaller than 6,000 barrels but with higher component concentrations.

The third concern involves a centralized sump that accepts drilling fluids from many wells, thus ending with only one treatment site. However, the effect of dumping many different sump fluids into a central pit increases the chances of an untreatable sump.

The fourth chemical concern pertains to the organic additives found in the muds/fluids. These organics vary greatly in amount and toxicity. Diesel fuels, starches, xanthum gums, sodium carboxymethyl cellulose, polyacrylates and oxide polymers are just a few of the organics used. Individually these substances are somewhat predictable as to their toxicity and also their ability to break down, if they are left to decay in a biologically active soil or left to degrade by photochemical oxidation. It would appear that certain additives are not readily degradable under either aerobic or anaerobic conditions, (polyacrylamides, lignosulfonates, xantham gums and asphalts). However, some "natural" compounds such as celluloses, starches, alcohols and diesel fuels are degradable, especially under aerobic conditions (Hutzinger and Veerkamp, 1981). When these organics are used in concert, their combined toxicity could become untreatable, a situation that has been experienced in Alberta. The additional complication of *in situ* alteration of these additives down hole has not been examined, nor has the effect of combinations of

organic additives and inorganic mud components. For example, what is the effect of the addition of sorptive clays on biodegradation of organic additives? What levels of salt are inhibitory to degradation of specific additives?

Physical Considerations

The second consideration that affects overall toxicity has to do with physical stratification of the sump contents. Sump contents are almost always found in a least three layers. In Alberta we have seen ample evidence of this feature. In Table 1, a stratified chloride, calcium and pH reading is shown. It is also likely that the organics are stratified in such a manner. After normal settling, a buildup of solids and organic materials may often occur at the bottom portion of the pit.

A second concern, related to physical segregation of the drilling wastes, possibly occurs after the fluid components have been clarified or the sump has been what is traditionally known as "detoxified". Detoxification can occur when the solids are precipitated using alum and when the waters are treated with activated carbon. Such treatment further concentrates many undesirable components at the solids layer towards the bottom of the pit. As the solids portion of drilling wastes have never been under regulatory control and as it does not usually receive proper chemical treatment, a concern arises about how this waste component should be disposed.

WASTE DISPOSAL OPTIONS IN ALBERTA

The Crown lands in Alberta are managed by two divisions which have different end land uses. The Alberta Forest Service desires to maintain a timber base and therefore tree clearing is minimized in the forested areas. The Public Lands Division manages the open range and agriculturally oriented Crown lands and is therefore not necessarily concerned about tree removal. Any tree clearing enhances agricultural capability. Therefore, drilling waste disposal methods will differ between the forested and the nonforested Crown lands.

Drilling waste disposal is handled by four basic methods or variations of these methods as directed by the two land-managing divisions. They are:

- 1) in pit burial
- 2) deep trenching or modified deep trenching and shallow trenching
- 3) standard squeezing
- 4) surface spreading

A fifth option, that of full chemical and physical treatment of sumps, is being tested in Alberta. The first two methods listed above were practised more commonly in the forested areas because of restricted working space. The second and third methods listed have been practiced most commonly on the open range. The first two methods are now being discouraged. The buried components tend to remain untreated in place and pose a potential

Table 1: Selected Analyses or Samples According to Depth Showing Stratification

Sample Elevation	Ca (ppm)	Cl (ppm)	pH
Surface	300	1650	7.1
3 ft.	350	2620	7.4
6 ft.	490	6900	9.2
8 ft.	560	7000	9.3
10 ft.	1520	7990	9.7

* G.A. Specken. 1975. Treatment and disposal of waste fluids from onshore drilling sites. A paper presented at the May 21-25, 1975 U.S. Environmental Protection Agency - A.P.I. Conference on Environmental Aspects of Chemical Use in Well Drilling Operations, Houston, Texas, U.S.A.

contamination threat to groundwater; contamination either by the salts or the organics. The standard squeezing technique whereby a cat slowly pushes the sump fluids out one end of the pit by pushing in fill material at the other end, is still acceptable. However, a portion of the solids still tend to remain behind in the pit. Therefore, removing the contents entirely by a backhoe and spreading them on the land surface is becoming the preferred method of drilling waste disposal.

Alberta has not decided on the best method of applying solid sump wastes to the soil surface. Up to the present, the Public Lands Division, where applicable or suitable, has suggested that straight drilling waste solids (i.e. bentonite gel muds) be spread onto the soil surface at a five to 10 cm depth. The amount would vary depending on the degree of toxicity. Spread rates for salt mud solids are still being requested at a rate of 450 kg of chloride/ha. The figure could be increased, depending on the site situation and the volume and concentration of mud. Public Lands Division has also recommended that 0.5 to 1.5 kg of gypsum per barrel of "land applied" waste be mixed into the drilling waste pit or the mud/soil component. Each site is treated individually; there is no standard approach. However, the Department of Forestry is beginning to ask that both the drilling waste and the receiving soil be analysed for electrical conductivity, pH, texture, sodium adsorption ratio, cations and nutrient status. From these two analyses, amendments may be recommended.

LAND APPLICATION CONSIDERATIONS

Surface land application of drilling wastes must be environmentally and economically feasible. As can be seen in Table 2 and Table 3, a recent analysis of KCl drilling waste, and another KCl, NaCl and fresh water drilling waste, shows that the two most crucial problems are electrical conductivity and the high sodium ion concentration. Given a suitable receiving soil and an adequate spread area, detrimental salinity and sodicity (when first washed, if necessary, and then augmented by a calcium amendment if needed) effects can be greatly minimized. Further, under favourable environmental conditions, the bacteria and fungi at the soil surface are capable of degrading a wide variety of organic compounds. Ultraviolet light can cause photochemical changes; in particular, photo-oxidation of hydrocarbons and aromatic compounds, possibly rendering the resulting molecules to be more susceptible to microbial attack (Edwards, 1983). With increasing depth in the soil profile, the absolute number of microbes decreases, generally leading to lower degradative capability. Therefore, drilling waste burial is not advisable.

Before surface spreading a drilling waste, several considerations are required. Firstly, the receiving environment must be suitable. Sandier sites are likely to benefit best from the waste. Sodic soils are poor receivers as well as areas that have high water tables, that are close to surface waters or that have shallow bedrock. Forested areas and mountainous areas have a limited land base for spread potential. High quality agricultural soils may not be acceptable for a waste spread.

Table 2: Productivity Ratings for a KCl_{*}Drilling Mud Waste as a Soils Component

Property	Value	Rating
Reaction (pH)	7.5	Good
Salinity (dS/m)	51	Unsuitable
Sodicity (SAR)	67	Unsuitable
Saturation (%)	62	Fair
Texture	L	Good
CaCO ₃ Equivalent (%)	12	Fair
Toxic Components	To be evaluated	

* Dr. C. Palmer. 1985. Drilling wastes as a soils component. A paper presented at the April 23-24, 1985 Drilling Wastes Reclamation Review Technical Advisory Committee Workshop, Edmonton, Alberta.

Table 3: Drilling Waste Soil Analysis

Hole No.	Saturation %	pH Paste	E.C. dS/m	SAR	Ca me/L	Mg me/L
1	55	8.10	6.14	6.63	27.20	16.00
2	100	12.44	11.84	299.60	0.05	0.05
3	62	8.40	197.30	676.60	65.00	5.95

Hole No.	Na	K	NH ₄ -N	NO ₃ -N	Cl	SO ₄	CO	HCO ₃
					me/L			
1	30.8	1.48	.085	.025	18.750	53.0	-	2.00
2	67.0	0.81	.320	.050	9.500	10.4	3.03	29.32
3	4030.0	9.60	.170	.105	3550.000	140.0	-	1.12

1 = fresh water gel mud sump
 2 = KCl polymer gel mud sump
 3 = NaCl saturated gel mud sump

A second component concerns the application method. Several possibilities exist that have not been adequately tested. Such possibilities are:

- a) Use of backhoe to extract waste from a pit and then use of a bulldozer to spread the waste
- b) Use of backhoe and a manure spreader
- c) Use of a sewage sludge spreader where waste is spread as a water slurry
- d) Use of a bulldozer alone
- e) Use of a vacuum pump and a bulldozer

Such site selection and application method concerns need to be more carefully examined.

ON-GOING WORK

The amount of literature concerning drilling wastes and the environment has been accumulating for at least 10 years. Within the past two years the waste material has received prominent consideration in Oklahoma, Saskatchewan and, now, Alberta. Because there is not a comprehensive review to date that deals with the material and its effects on the environment, Alberta Environment, under the guidance of the Reclamation Review Technical Advisory Committee (RRTAC), commissioned a consultant to compile a major report on drilling wastes. The consultant was directed to review drilling wastes and their potential effect on the environment and to prepare a field manual to help government field staff decide how best to dispose of drilling wastes in any given general location. From this report and on-going field work, further research will likely occur concerning drilling waste disposal.

CONCLUSION

Given the complexity of inorganic and organic chemicals used in North America, all possible treatment and disposal options should be carefully reviewed for drilling wastes. Despite the existing regulations for on and off lease drilling fluid disposal and down hole fluid disposal, the most effective means for mitigating environmental problems caused by drilling waste solids disposal is yet to be developed.

Disposal options will vary according to geographical location and site conditions. Full chemical treatment and dewatering systems should be considered for areas within forested regions where land spreading is restricted because of a desire to maintain a timber base. Land application of drilling wastes could occur on open agricultural areas where soil textures are suitable, the terrain is relatively flat to allow machine work and prevent runoff, and water tables are not near the soil surface. Drilling waste burial of any form should rarely occur unless absolutely necessary and only if the muds are well removed from urban areas, farm areas, watercourses, high water tables, and all but tight clay land fill sites. In this latter case, the muds should be detoxified of both salts and organics before burial. As long as the economics of waste disposal are not excessively prohibitive,

the most environmentally safe disposal method should always be used.

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APPENDIX I: Interim Directive No. ID-OG 75-2 Sump Fluid Disposal Requirements

1.0 Disposal of Sump Fluids to a Subsurface Formation

Disposal of sump fluids to a subsurface formation is an acceptable procedure provided:

- a. Approval is first obtained from the Energy Resources Conservation Board.
- b. The subsurface formation is not locally productive of oil or gas.
- c. The formation water in the disposal zone has a total dissolved solids content greater than 20,000 mg/L.

2.0 Disposal of Sump Fluids on the Lease

Disposal of sump fluids to the lease is an acceptable procedure providing all of the following conditions are met:

- a. Notice of at least one week has been given to:
 - i. the appropriate District Office of Alberta Energy and Natural Resources if the well was drilled on any public land in the province.
 - ii. the appropriate Area Office of the Energy Resources Conservation Board if the well was drilled on any other lands not specified in section 2.0 (a).
- b. The entire contents of the sump are confined to the lease.
- c. The sump(s) contain less than a total of 6,000 barrels of fluid. Notwithstanding this limitation, approval may be given by the Board or Alberta Energy and Natural Resources to dispose of more than 6,000 barrels of fluid to the lease providing it can be shown that the entire contents of the sump will be confined to the site. Applications for such approval shall be directed, in the appropriate way, to either the Area Office of the Energy Resources Conservation Board or District Office of Alberta Energy and Natural Resources.
- d. The lease is more than 300 feet from the normal high water mark of a body of water, permanent stream or potable water well.
- e. The lease site will, in the opinion of the Energy Resources Conservation Board or Alberta Energy and Natural Resources, accept the sump contents to be

disposed, without run-off.

3.0 Disposal of Sump Fluids off the Lease

3.1 Disposal of sump fluids to off-lease land areas is an acceptable procedure providing:

a. The sump fluids meet the following criteria:

Chloride content	1000 mg/L Maximum
Sulphate content	2000 mg/L Maximum
Total Dissolved Solids	4000 mg/L Maximum
pH	5.5 to 8.5
Trout Survival Test	96 hours (See Appendix B - Guidelines Used to Determine Fish Toxicity Tests on Sump Fluids).

b. Approval to dispose off the lease has been obtained in accordance with section 3.3.

3.2 The Energy Resources Conservation Board or Alberta Energy and Natural Resources will consider off-lease disposal which is not according to the criteria outlined in Section 3.1. Application shall be made, in the appropriate case, to the Area Office of the Energy Resources Conservation Board or the District Office of Alberta Energy and Natural Resources.

3.3 Off-Lease Disposal Approval

3.31 On public lands throughout the Province, disposal of well sump fluids to land off the lease and the location of the disposal site must be approved by the appropriate District Office of Alberta Energy and Natural Resources.

3.32 On all land not described under subsection 3.31, disposal of well sump fluids to land off the lease must be approved by the Energy Resources Conservation Board, subject to the disposal and disposal site having been approved by the landowner.

3.33 Any licensee of a well who intends to dispose of fluids to land off the lease area shall:

- a. sample the fluids according to the procedure outlined in Appendix A.
- b. analyze and field-treat the sump fluids so that the fluid to be disposed of meets the criteria outlined in section 3.1. Tests must conform to the guidelines outlined in Appendix B.
- c. two days prior to treating the fluids and depending on whether the lease is located on public or other lands, notify, in the appropriate case, the District Office of Alberta Energy and Natural

Resources or the Area Office of the Energy
Resources Conservation Board.

3.34 The request for approval to dispose of sump fluids to land off the lease area must be submitted, in the appropriate case, to the District Office of Alberta Energy and Natural Resources or the Area Office of the Energy Resources Conservation Board, and contain the following information:

- a. a description of the sampling procedure.
- b. a general description of the method of treatment of the sump fluids.
- c. an analysis of a representative sample of the treated sump fluids (including trout survival test).
- d. the location of the disposal area and the volume of sump fluids to be disposed of.
- e. a brief description of the surrounding area (i.e., whether it is forested, muskeg, swamp and the kind of vegetation present).
- f. in the case of disposal to private lands, a statement that the landowner's permission has been obtained to dispose to the off-lease site.

3.4 Disposal of well sump fluids to any surface water either directly or indirectly by land surface drainage must be approved by Alberta Environment. Only under rare circumstances, and where sufficient lease land or peripheral land disposal sites are not available, is such disposal considered.

APPENDIX II: Interim Directive ID 81-1, Energy Resources
Conservation Board, Calgary, Alberta

TO: ALL OIL AND GAS OPERATORS

Subsurface Disposal of Drilling Fluids

This Interim Directive supersedes Interim Directive ID 70-3 issued on 15 December 1970.

The Board will permit operators to dispose of drilling fluids not only in dry holes but to any well where subsurface disposal of drilling fluids is feasible.

The Board believes that under appropriate constraints the subsurface disposal of drilling fluids can be carried out without jeopardizing any subsurface potable water horizons. It will consider such disposal as part of the drilling or completion program for a well and separate approval under section 38 of The Oil and Gas Conservation Act will not be required. The subsurface disposal of drilling fluids may be carried out subject to the following conditions:

1. Permission of a Board representative shall be obtained before any disposal operation is commenced.
2. The disposal zone shall be at a depth not less than 600 meters.
3. The resistivity directly attributable to the total natural dissolved solids in the FORMATION WATER of the disposal zone shall be less than 0.33 ohm/m corrected to 20°C (equivalent to 20,000 ppm total dissolved solids).
4. The disposal zone shall be known not to contain hydrocarbons within two kilometers of the intended disposal well.
5. Where a well is to be abandoned or plugged back and does not contain at least 600 meters of casing cemented in place:
 - a. the disposal of fluids shall be through drill pipe and below a seated packer, and
 - b. the annulus between the drill pipe and the surface casing shall remain open to the atmosphere during any disposal operation.
6. Where a second casing string has been run in a well and not cemented to surface:
 - a. the disposal of fluids shall be through the annulus

between the casings, provided the surface casing is deeper than 600 meters,

- b. the disposal zone shall be identified by depth and geological designation,
 - c. the fluids to be disposed shall be displaced out of the annulus with a corrosion inhibited fluid. If, after displacement, pressure exists in the annulus, cement shall be displaced into the formation to seal off the disposal interval, and,
 - d. the annulus shall be left open to the atmosphere in the manner described in subsection 6.100(2) of The Oil and Gas Conservation Regulations.
7. Where the disposal zone has been cemented behind casing:
- a. the disposal zone shall be identified by depth and geological designation,
 - b. the casing shall be perforated and the fluids disposed of through the perforations, and
 - c. the perforations shall be appropriately sealed or isolated.

ISSUED at Calgary, Alberta, on 12 March 1981.
ENERGY RESOURCES CONSERVATION BOARD

SUBJECT: Potassium-Based Drilling Mud Systems

In recent years some companies have chosen to use potassium-based drilling mud systems in special situations, particularly on the deeper wells being drilled in the Eastern Slopes Region of Alberta. The result has been large accumulation of fluids which represent a disposal problem because of their toxicity to aquatic life and to vegetation. No method currently exists to remove the potassium component.

Problems can be minimized if disposal is planned by the lessee prior to the commencement of drilling. An option that should receive special attention is contained in the Energy Resources Conservation Board's Interim Directive ID 81-1 of March 12, 1981, Subsurface Disposal of Drilling Fluids.

Commencing immediately, lessees of public lands who plan to use potassium-based drilling mud systems will be required to submit a plan for disposal of the fluids resulting from the drilling operation. Plan approval must be obtained from the field office of the Department designated in the surface lease conditions prior to the commencement of lease construction.

Further information may be obtained from the following persons:

Public Lands Inside the Green Area

Mr. W.N. Barnes
Forest Land Use Branch, Alberta Forest Service,
Alberta Energy and Natural Resources,
Bramalea Building, 9920 - 108 Street,
Edmonton, Alberta T5K 2M4
Telephone: (403) 427-3587

Public Lands Outside the Green Area

Mr. D.G. Blackmore
Land Management and Development Branch, Public Lands Division,
Alberta Energy and Natural Resources,
Petroleum Plaza, South Tower, 9915 - 108 Street,
Edmonton, Alberta T5K 2C9
Telephone: (403) 427-5209

FOREST SOIL AMENDMENT WITH MUNICIPAL AND INDUSTRIAL SLUDGE

Dale W. Cole

Associate Dean, College of Forest Resources
University of Washington
Seattle, WA 98195

Charles L. Henry

Sludge Program Director, College of Forest Resources
University of Washington
Seattle, WA 98195

ABSTRACT

Research in soil improvement of forest stands with municipal sewage sludge has been carried out by the University of Washington College of Forest Resources during the last 13 years. In 1973 the College entered into an intensive research program, funded by the Municipality of Metropolitan Seattle, investigating the concept that municipal sewage sludge could improve forest soils and enhance tree growth. This program was and continues to be conducted at the University's Charles Lathrop Pack Demonstration Forest near Eatonville, WA.

Municipal sewage sludge contains a relatively high concentration of nitrogen (4-6%) in both available and organic forms. Virtually every other nutrient required for plant growth is also provided by sludge. Additionally, due to the organics and fine particles in sludge, it acts as an excellent soil conditioner.

Experiments in sludge applications at Pack Forest for the most part have been conducted on soils of low productivity, which have an advantage for test plots. These soils are typically nutrient deficient and coarse textured, and thus positive growth results are quickly evident. Additionally, these soils are well to excessively drained, and constituents which are not utilized or stored in the system are quick to show up in leachate and drainage waters. A variety of tree species have been grown in sludge amended soil in test plots in these studies.

This presentation will include some of the 13-year history of the Pack Forest Program which has led to development of appropriate application techniques and rates and expected growth response of trees of the Pacific Northwest, and has also aided in the development of national, state and local guidelines.

INTRODUCTION

Nearly 7 million dry metric tonnes of municipal sewage sludge are produced yearly in the United States, along with over 2 million dry metric tonnes of industrial pulp and paper sludge. Traditionally these sludges have been "disposed" of by 1) ocean dumping, 2) burying in a landfilling, or 3) incineration. As an alternative to the "disposal" philosophy, practices "utilizing" sludge as a soil amendment have been gaining popularity due to the nutrient content and soil conditioning properties of sludge. The utilization alternatives available for land application include: 1) use in forested sites, 2) use in agriculture, 3) soil reclamation, and 4) composting or drying.

Although the use of sludge on agricultural land in the U.S. is widespread, forested areas are receiving increased attention as potential sites for biological treatment and recycling of municipal and industrial sludges. Table 1 shows that within the United States a number of cities are either currently practicing or are operating research and/or demonstration programs in forest land applications, and more cities are becoming interested as this practice becomes accepted. Research during the last decade has shown that with appropriate application rates drainage water quality can be maintained at a high standard while the productivity of the forest crop is enhanced.

There are a number of reasons for considering forested sites as potential candidates for the reuse of municipal and industrial sludge:

1. In many areas extensive acreages of forest land are potentially available for such a program.
2. Many forests are located in sloping areas with good drainage and are not subject to the periodic flooding of alluvial areas.
3. Many forests are limited in productivity due to a deficiency in major nutrients that are found in sludges, especially nitrogen and phosphorus. A lack of adequate nutrition is the main factor limiting forest productivity.
4. Since trees are not food-chain crops, many of the public health concerns and land application regulations should not be as critical as those associated with agricultural sites.
5. Forest soils theoretically have properties well suited to receive sludge additions, including a great deal of organic carbon which immobilizes available nitrogen, a high infiltration rate which should minimize the potential for surface runoff, and a perennial root system which should allow for year round uptake of available nutrients.

Table 1: Existing Research and Operational Forest/Sludge
Application Projects in the U.S.

Florida	Oregon
Citrus County	Seaside
	Wanna Paper Mill
Illinois	South Carolina
Shawnee National Forest	Savannah River Laboratory
Pope County	
Michigan	Tennessee
Pipe River Experimental Forest	Tennessee Copper Basin
Udell Experimental Forest	
New Hampshire	Washington
Hubbard Brook	Pack Forest Experimental
	Forest
	Seattle Metro
North Carolina	Tacoma
Conway	Bremerton
	Woodland and Richfield
Ohio	Shelton
Wooster	Long Beach

Forest applications of sludge, however, raise potential conflicts with traditional uses of the forests, especially those involving recreation. For example, sludge sprayed over vegetation has a temporary displeasing appearance and odor, and concerns over heavy metal uptake by mushrooms and berries have been raised. It has also been suggested that sewage sludge additions could adversely affect the forest wildlife, and through such wildlife, toxic substances could enter the human food chain.

More tangible concerns have also been raised. Many forested sites are located in areas of excessive slopes which could allow escapement of sludge particles or dissolved solids through surface water runoff. It is also suggested that tree species in their natural setting generally take up far fewer nutrients than agricultural crops, possibly resulting in more time for nutrient escapement or transformation. Also not all tree species respond significantly to or are appropriate for nutrient additions.

Most importantly, it has been pointed out that there is far less experience and substantive research dealing with forest applications than with agricultural applications, and therefore the design of sludge use for a forest site is more speculative. Fortunately, much of the research conducted on agricultural sites is relevant to forest situations. Excellent summaries of such work are reported in the Workshop on Utilization of Municipal Wastewater and Sludge on Land edited by Page, *et al.* (1983).

The questions regarding forest applications have not been largely resolved, and fully operational forest sites now receive sludge additions. Forest/sludge applications have been under way both in this country and elsewhere for over a decade documenting the effects of applications in forested sites (Table 1). These studies have lead to the development of appropriate application technology.

OBJECTIVES OF LAND TREATMENT

Simply stated, the desired goal of a sludge land application program is to treat and utilize the waste in an environmentally safe and cost effective manner in comparison with other treatment and/or disposal alternatives. Research and demonstration sites have shown that the desired goal can be met on a variety of site and vegetation conditions. Forests have shown a capacity to treat and utilize sludge and to improve in economic value as well. Specifically, the objectives of a forest land application program are:

1. To treat sludge in an environmentally safe manner;
2. To fully utilize and thereby receive maximum benefit from the fertilization and soil conditioning properties of sludge;
3. To minimize the potential of environmental impacts from the sludge application procedure and the sludge itself with particular attention paid to ground water and surface water impacts, and controlling aerosols beyond an

established buffer zone;

4. To optimize the economics of the sludge management program, i.e. to minimize costs of application while maximizing returns from forest growth response.

The use of the land as a natural purification system has a long history as discussed by Dean and Lund (1981) in their book on Water Reuse. It is the purpose of a land treatment system to use the soil and vegetation as the means by which renovation is achieved. It should be recognized that there has not been any verified specific instance of a public health problem caused by land application of sludge in recent years (Kowel, 1983). The forest system provides renovation and public health protection in the following ways.

Ground Water Protection

All solutes from sludge and in leachates resulting from net precipitation (rainfall - evapotranspiration) are retarded when passing through the soil system, that is the movement of water is greater than the movement of the solutes. This delay is caused by a variety of chemical, physical, and biological processes that will be described in greater detail later. It is from a combination of such processes that allows treatment and beneficial use of the sludge constituents to occur. However, not all solute constituents move through the soil at the same rate, nor is the amount of treatment provided the same. Organic compounds that are biodegradable are converted to CO_2 . Substances that are precipitated, such as phosphates and heavy metals are strongly adsorbed on the soil mineral surfaces and simply add to the soil mass and are permanently removed. Cations, such as Mg^{++} , Ca^{++} , and NH_4^+ , are initially removed by the ion exchange properties of the soil. This represents only a delay in their passage through the soil and not necessarily a permanent removal. A further delay from leaching and potentially permanent removal is achieved for such ions by uptake and utilization by the crop. Anions, such as nitrate, have a minimal delay and can rapidly move to the ground water. Consequently, it is important to minimize the presence of nitrate through the proper design and management at the land treatment system as will be discussed later.

Surface Water

Proper design of the land application site will minimize the possibility of surface runoff. Clearly, any sludge that has not reacted with the soil, as outlined above, will still contain many if not all of its original constituents, and will considerably affect a receiving water body if allowed to flow directly into a drainage channel. To minimize runoff it is essential to provide buffers from water bodies, and not exceed maximum slope recommendations. Forested sites have a continual forest floor, and can safely receive sludge at slopes up to 30-40% compared to 8-12% recommended for agriculture. In general, forest soils have excellent infiltration rates because of the presence of this forest floor layer. In addition most forest soils have far greater porosities than agricultural soils. Both of these facts

result in little if any runoff and make forests excellent candidates for land application systems.

Aerosols

The third way in which sludge constituents, especially pathogen laden aerosols, can leave a land application site is from aerosol dispersion during periods of applications. This movement is dependent on the design of the application system, and the rate of wind movement during an application period. It has been well documented that the rate of wind flow is greatly modified by the presence of a forest stand. Typically a 70 to 90 percent reduction in wind speed is found 50 m within a forest stand. Consequently, buffers to prevent the movement of aerosols from a forest land application system can be relatively narrow.

Description of the Renovation Process

As discussed above, a land application system should provide excellent treatment and use of the constituents in sludge. The process of renovation involves chemical and physical as well as biological reactions with the soil-plant system. The role of these reactions in providing renovation is discussed below.

Chemical

Most of the ionic constituents in leachates from sludge are initially removed from solution through chemical reactions. Some of these reactions, such as ionic replacement on soil exchange sites, provide only temporary removal whereas precipitation reactions can result in the permanent removal of the reacting ions from the soil drainage waters.

In general, anions will leach through the soil far more rapidly than cations due to the negative surface charge of most soil colloids. Two in particular, nitrate and chloride, will rapidly leach if present in sufficient concentrations. In contrast, K^+ , Ca^{++} and Mg^{++} will be removed by cation exchange reactions. There are important exceptions, however, to this general statement. Phosphorus, an anion and major constituent in sludge is readily precipitated from the soil solution typically as a calcium or iron phosphate depending on the pH of the soil. The capacity of the soil to remove P is exceptionally high resulting in P not being a problem in any land application system.

NH_4^+ is removed from sludge leachate by the exchange potential of the soil colloids, the same basic process discussed above for K^+ , Ca^{++} and Mg^{++} . However, in the case of NH_4^+ , this storage can be very temporary if nitrification occurs.

Almost all heavy metals are strongly adsorbed on soil particles. This is especially true if the soil is neutral or basic. Heavy metals can also be bound to organic chelating agents that convert them to anion complexes. In this form they readily move through the soil similar to the movement of other non-negative anions. Much research has been done on heavy metals in agricultural applications. A specific review article was written

by Logan and Chaney (1983). Zasoski (1981) reported that heavy metals are relatively immobile in plants and soils in a forest site.

Physical

The physical filtering process in a land application system is very important in assuring desired drainage water standards. Most importantly, it slows down the rate of percolation, increasing the time for chemical and biological reactions to occur. This filtering process also results in the removal of microorganisms and organic matter where they can be degraded over time. Non-biodegradable organic matter will be adsorbed to the soil surfaces and will not leach through the soil profile.

Much of the filtering process in forests takes place in the forest floor layer. Therefore, there is less of a tendency to clog the surface soil pores with organics (which decrease the infiltration capacity of the soil) associated with the sludge.

Biological

The "living" phase of the soil is also critical to the overall renovation process associated with land application. For example, it is responsible for the removal of pathogenic organisms and viruses as well as the uptake of nutrients, especially nitrogen, by the crop plants. The role of the "living" phase in the renovation process is perhaps even more important in forest systems than for agriculture crops.

Microorganisms associated with sludge are initially filtered out and then replaced by the indigenous organisms of the soil. The survival time for most microorganisms following land application is typically very short but is dependent on a variety of soil and climatic conditions including temperature, moisture content and pH. Bacterial pathogens will generally die off to negligible numbers within 2 to 3 months following application (Gerba, 1983; Edmonds, 1979). Viruses will commonly survive a maximum of 3 months, while protozoa will survive for only a few days (Kowel, 1983). In any case these microorganisms will not leach through the soil system and present a public health problem for the receiving groundwaters (Edmonds, 1979). They will remain in the surface soils for the duration of their survival period. Only if the site is subject to surface runoff will pathogens enter into receiving water bodies.

Forest soils, especially those with a well developed forest floor layer, are excellent systems to renovate organic solutes, compounds and solids. Typically, toxic organic compounds are not important constituents in sludge derived principally from domestic sources or pulp and paper sludges, and therefore not a problem in land application systems. Even when toxic organic compounds have been present in the sludge, they have not presented a limiting parameter for the function of the land treatment system (Overcash, 1983). Organic compounds are readily sorbed to the organic surfaces of the soil system and thus have limited mobility through the soil profile. In that these organic compounds are typically

biodegradable, they will not accumulate to any extent in the soil.

The living phase of the soil is also responsible for nutrient removal by plant uptake processes. In order for soil nutrient renovation, especially nitrogen renovation, to function over an extended period of time, the added nutrients must be removed by plant uptake. The rate of uptake that can be expected for forest species in land application systems was reported for each major region by McKim *et al.* (1980) and Brock *et al.* (1986). In general, uptake and storage by forests can be as large as that of agriculture crops if the system is correctly managed and species capable of responding to sludge are selected. Uptake and storage rates exceeding 300 kg/ha/yr have been reported for 3-5 year-old poplar and 200 kg/ha/yr for Douglas-fir ecosystems of the same age (Schiess and Cole, 1981). This utilization rate for nitrogen compares favourably with uptake for almost any agricultural crop.

Design Philosophy

Important to proper design of a forest application site is understanding the characteristics of the system. Unlike agriculture, forest systems contain continual crops (trees), forest floors and mineral horizons. To most effectively design a site may require specific site studies to establish relationships between uptake rates and nutrient and mineral cycling. Forest application projects do not have the years of experience of agricultural sludge applications to draw upon for site and species selection, application amounts, timing of application (both tree age and season of the year), and for the development and testing of equipment capable of meeting the unique conditions of placing sludge in a forest environment. From the University of Washington's research experience at Pack Forest and other research from around the United States, we have developed the following application guidelines and procedures. These recommendations currently are the basis for the forest application sections in U.S. Environmental Protection Agency's Process Design Manual (USEPA, 1983) and other guidelines (WDOE, 1982).

APPLICATION RATES

Nutrients

A balance must be achieved between application rates low enough that no environmental integrity is compromised from excess nutrients leaving the site and application rates that assure nutrients for a maximum growth response, while at the same time rates that are responsive to site development and application costs. The three macronutrients most commonly considered in terms of need by plants are nitrogen, phosphorus and potassium. Nitrogen has been traditionally considered the most important in determining fertilizer or sludge application rates because it is needed as a soil supplement in much greater amounts than the other two, and can, in the form of nitrate, be quite mobile in the soil.

Nitrogen

Municipal sewage sludge contains large amounts of nitrogen.

Sommers (1977) reported an average concentration of nitrogen of 4.2% in anaerobic sludge and 4.8% in aerobic sludge. Typical anaerobic sludge contains nitrogen existing in an organic form (80%) and available forms as ammonium ion (19%) and nitrate ion (1%) (USEPA, 1983). Pulp and paper sludge range from 0.05% to 8.75% nitrogen, greatly dependent upon being primary or secondary sludges (Thacker, 1986). Except in special cases where heavy metal concentrations are very high due to large industrial inputs, application rates are limited by nitrogen loading (USEPA, 1983). This is especially the case in forest sites where a non-food chain is being grown. Nitrogen immediately available from sludge additions and available shortly after, through decomposition of the organics can follow a number of pathways:

1. Surface applied sludge can lose available nitrogen through volatilization of ammonia (Sommers, 1980).
2. Depending on soil conditions, denitrification losses can occur (USEPA, 1983).
3. The trees and understory can utilize the nitrogen as a nutrient, producing an increase in growth.
4. Nitrogen is stored in the soil. Because forest soils include an organic layer containing decaying litterfall, twigs and branches, the soil has a wide carbon to nitrogen (C:N) ratio which will temporarily tie up available nitrogen (Schiess and Cole, 1981).
5. The remaining available nitrogen not taken up by the vegetation or soil microorganisms can be nitrified, with the resulting nitrate free to leach into the ground waters (Cole and Henry, 1983). Excessive nitrate (over 10 ppm) in drinking water is a potential health concern, and, therefore, sludge applications over open aquifers should be designed to have minimal nitrate leaching.

In order, then, to have both maximum utilization of the nitrogen from the sludge and to assure minimal effect to the environment, one must have adequate knowledge of the concentrations of nitrogen compounds as the sludge is applied, and must proceed through calculations estimating above processes. Table 2 presents a conceptual model for a nitrogen balance for three types of Douglas-fir forests. The assumptions include:

1. Initial sludge characteristics are 3.9% organic nitrogen and 0.7% ammonium-N.
2. 20% organic nitrogen mineralized in the first year (Edmonds and Cole, 1980).
3. Ammonia volatilization = 25% of ammonia initially applied in young stands and clearcuts, negligible volatilization in older unthinned stands (Edmonds, 1985; Henry, 1982).
4. Denitrification = 25% of total annual available nitrogen (USEPA, 1983; Edmonds, 1985).

Table 2: First Year Conceptual Nitrogen Balance for Sludge Application to Forest Soils. (+ indicates accumulation, - indicates loss)

Sludge Application			Nitrogen Transformations and Leaching					
Dry T/ha	Organic N	Ammonia N	Vol. N	Min. N (kg/ha)	Denit. N	N Uptake	Stored N	Leached N
<u>Clearcut</u>								
25	961	172	-43	+192	-81	-134	-106	= 0
49	1922	345	-86	+384	-161	-134	-196	= 152
<u>Young Stand</u>								
25	961	172	-43	+192	-81	-213	-27	= 0
49	1922	345	-86	+384	-161	-213	-196	= 73
<u>Older Unthinned Forest</u>								
25	961	172	0	+192	-91	-48	-196	= 29
49	1922	345	0	+384	-182	-48	-196	= 303

5. Long-term soil storage = 196 kg-N/ha (Schiess and Cole, 1981).
6. First year above-ground storage (Schiess and Cole, 1981; Dyck *et al.*, 1984):
 - clearcut: 11 kg-N/ha in trees
 123 kg-N/ha in the understory
 - young stand: 101 kg-N/ha in trees
 112 kg-N/ha in the understory
 - older unthinned forest: 26 kg-N/ha in trees
 22 kg-N/ha in the understory

Phosphorus and Potassium

Phosphorus is generally found to be at concentrations in sludges equal to about two-thirds of nitrogen concentrations, yet only needed by plants at rates equal to about 20-50 percent of that for nitrogen. Therefore it seldom limits plant growth when application rates are based on nitrogen needs. Precipitation and sorption of phosphorus in the soil are responsible for its limited availability, and this fixation in the soil restricts the movement of it to ground water to very low levels. Furthermore, excessive phosphorus build-up in the soil poses no threat to forest plants or the environment.

In contrast to phosphorus, potassium is supplied at only about one-tenth the concentration of nitrogen from sludges, yet is removed by plants at levels equaling nitrogen. Therefore, it is unlikely that a build-up of potassium can occur from a sludge application. Potassium is generally found in comparatively high concentrations in soil and seldom is a limiting factor for growth.

Heavy Metals

Although heavy metals are generally not a limiting parameter, repeated applications of sludge could approach maximum accumulated metals loadings suggested for agriculture. It can be argued that these limits need not apply to forest applications since forest crops are non-food chain, but for land with potential future uses other than forestry, it is recommended to stay within the limits listed in Table 3.

Specific Organic Compounds

The only group of organic compounds addressed in U.S. Federal Regulations is PCB's, which requires that sludges containing greater than 10 mg PCB/kg be incorporated into the soil. The main purpose for this is to limit direct injection by grazing animals. In most cases the concentration of PCB's in sludge is well below that level.

Pathogens

Pathogens are not generally used as a criteria for designing

Table 3: Accumulated Heavy Metals Loadings Recommended for Agricultural Applications (WDOE, 1982).

Element	Soil Cation Exchange Capacity (meq/100g)		
	0-5	5-15	15
Lead	445	890	1780
Zinc	222	445	890
Copper	111	223	445
Nickel	45	91	182
Cadmium (pH > 6.5)	4.5	8.9	17.8
Cadmium (pH < 6.5)	4.5	4.5	4.5

application rates. However, sludge treatment which "significantly reduces pathogens" is required, and can be accomplished by a number of methods including anaerobic and aerobic digestion of sludge.

SITE EVALUATION CRITERIA

General Conditions

Since the objectives of sludge application to a forested site are to enhance tree growth and minimize operational costs, it is important that potential sites be evaluated with these objectives in mind. In particular, consideration must be given to physical factors of a potential site such as a) topography, b) soils, c) hydrologic aspects, d) vegetation (stand and understory characteristics), e) land size, and f) climatic conditions, and social and economic factors of a site such as g) land use and neighboring ownership, h) control of land, i) distance to the site from the treatment plant, and j) permits and monitoring required.

Terrain Factors

Probably the most important criterion which will quickly indicate the usability of a site is the topography. Important considerations are slopes, continuity, elevation, and aspect. Slopes and continuity have major impacts on the usability of sites and development costs. Elevation will affect the number of days a site may be unsuitable for applications due to snow or freezing. Aspect of the site is important in the amount of solar radiation an area receives, which will aid stabilization of the sludge lifts and thaw of snow or frozen ground.

Soil and Geologic Factors

Fortunately, some of the easiest sites to develop and operate on have soils which can biologically benefit the greatest from sludge addition, such as the gravelly outwash soils. These soils not only are deficient in properties which can be supplied by sludge (nutrients and soil tilth), but also usually are better drained. Trafficability, infiltration/percolation, depth of soil, pH, and cation exchange capacity (CEC) all play important roles.

The importance of geologic factors lies in their relationship to ground and surface water hydrology in creating zones impermeable to downward water movement.

Vegetation Factors

Site vegetation is an important consideration in immediate acceptability of a site. Stand age and condition affect method of application and effectiveness in achieving even applications. Tree species affect the rate of sludge application. A well established understory provides increased nutrient uptake, aids in sludge stability and provides irregular surfaces which will minimize runoff possibilities.

Water Resource Factors

Sludge application rates are designed to minimize impact on groundwater. In order to evaluate the effect this leaching has on a groundwater aquifer, the dynamics of the aquifer should be known so that concentrations of nitrates in the groundwater can be estimated. Important characteristics are net precipitation, recharge area and size of the aquifer. Additionally, distance to groundwater table should be greater than 0.7 m throughout the year.

Nearness to waterways will eliminate portions of a site to protect against pollutants entering waterbodies via runoff or sludge erosion. If there are a number of drainage ways within or adjacent to a site, the site will obviously have less net usable area. An application area should not generally be in a watershed used for drinking water supplies. Sites with standing surface waters and flooding potential should always be avoided.

Forest Access System

A major cost of site development is construction of appropriate access road and trail systems. On many forest sites a significant portion of these systems already exist, especially those which are intensely managed and have had recent commercial thinning operations.

Transportation Distance and Cost

Quite often hauling sludge to the site is the greatest expense in an application program. Therefore distance should be included as a major site selection criteria. In addition to the distance, the class of roads affect hauling costs. Also routing of long-haul vehicles is an important factor, with consideration given to weight limits of roads and bridges, and travel through sensitive areas (population centers).

Climatic Factors

Climatic factors to consider in site evaluation include temperature and precipitation; important in the number of days during the year when snow, freezing conditions or rain can be expected to interrupt operations.

Wildlife Factors

Researchers to-date have found no significant adverse effects on health of wildlife. Although elevated levels of heavy metals have been found in the organs of some of the small mammals that live in the sludge-soil, there is no evidence of significant accumulation in the food chain. Positive effects have also been shown; increased vigor in animals that browse on the higher nutritional foliage. Increased populations of wildlife have also been found. Although hunters are limited from access to the site for a period of one year following the final application, they may later see an increase in both numbers and size of wildlife.

APPLICATION PROCEDURE

Three options have been tested for applications to forest lands:

1. Sludge applied to recent clearcuts
2. Sludge applied over the canopy of a young plantation
3. Sludge applied under the canopy of an older stand.

Clearcuts

Clearcuts offer the easiest, most economical sites to apply sludge. Since application will take place prior to tree planting, many agricultural sludge application methods are appropriate. Vehicles delivering sludge from the treatment plant can discharge semi-solid sludge (15+%) directly on the land followed by spreading by a dozer and disking. Ease of delivery will depend upon the amount of site preparation (stump removal, residual debris burning, etc.), slopes, soil conditions, and weather. Other options available are temporary spray irrigation systems, injectors and splash plates for more liquid material, or manure spreaders for more solid material. Again, site preparation and characteristics are major factors in application technique.

While clearcuts are easier to apply to, they also have major drawbacks. Because a site applied with sludge suddenly has an abundance of nutrients, grass and weed growth can be vigorous. Plantation establishment becomes much harder due to vegetative competition, and leads to much higher mortality if grasses are not held in check by extensive plantation maintenance. Vigorous subordinate vegetation also offers excellent protection for rodents such as voles, which can proliferate and add to seedling survival problems from trunk girdling. Deer browse can also be a major concern before young trees are above browse height. If application to a clearcut is planned, a program of periodic disking and herbiciding should be followed to control grasses and voles. Tree trunk protection devices are also available which provide a barrier against rodent girdling. Additionally, a fence or bud capping may be required to prevent excessive deer browse.

Young Plantations

Applications of sludge to existing stands decrease problems with competition, rodents and deer. Sludge is typically applied by a tanker/sprayer system, which can apply 18 percent sludge over the canopy 50 m into the plantation. This method requires application trails at a maximum of 100 m intervals. Timing of applications is important with over the canopy applications. To aid in washing sludge from the foliage and to keep sludge off new foliage, spraying should take place during the rainy non-growing season. Sludge sticking on new foliage could retard the current years growth. Sludge not dewatered has also been successfully applied via sprinkler irrigation system. Clogging of nozzles has been the major drawback to application by sprinkler irrigation.

Manure spreaders are capable of applying dewatered sludge which cannot be sprayed. Application trails, however, must be at close intervals.

Older Stands

Applications to older stands have the advantage that sludge can be applied year-round because the foliage will not be affected. Since spraying will take place under the canopy, no foliage will be affected. Application methods are similar to those described for young plantations. Typically stands are not in rows, which may eliminate some of the alternatives available for plantations.

Application Rate/Timing

Two application rate/timing philosophies exist:

1. Annual applications designed to meet only the annual uptake requirements of the trees, considering volatilization and denitrification losses, and decomposition from current and prior years.
2. A heavier application rate one year followed by a number of years when no applications are made. This schedule depends on the soil storage to temporarily tie up excess nitrogen which will become available in later years.

The second technique has some definite advantages. Application costs are lower due to entry into a site less frequently, and the public can use the site for recreation in the non-sludged years. Additionally, the excess available nitrogen present during the first year is no longer at elevated levels in following years, and leaching of nitrate in these years usually will not occur. Sludge, however, remains noticeable for a longer period of time than with lighter applications. If sludge is at a low percent solids (<10%), annual applications may be preferred. With heavy applications at low percent solids, the total quantity of sludge applied may exceed the site's capacity to treat the sludge. Surface sealing can then occur increasing the potential for runoff, and increasing anaerobic conditions which can cause odor problems.

Heavy applications should be made in a series of three or more partial applications depending upon the percent solids. This allows more even applications to be made and time for stabilization or drying of the sludge to occur; important for maintaining infiltration and controlling runoff. The "rest" between applications will range from 2 to 14 days depending on weather conditions.

Storage

Since sludge generally will not be able to be applied as consistently as it is produced from the plant, some temporary storage will be required. Options for storage are dependent on land availability and constraints of the treatment plant and

application site, the nearness to and ownership of the sites, and operational and management objectives. Two of the options available are:

1. Temporary storage at the treatment plant. Operationally, then, sludge would leave the plant as it was immediately ready for application. This is much more attractive for the landowner, as he would not have to take his land out of productivity for such as a storage lagoon, nor would he have the liability associated with a lagoon. This option also creates maximum flexibility for application. Use of multiple sites is not limited by the expense of multiple lagoon construction. Also, within a large site, transportation from the lagoon to the application area can be kept to a minimum. This option can be accomplished with 1) multi-purpose application vehicles that can travel both highway and forest roads, or 2) transfer trailers to supply sludge to an off-road application vehicle. One tractor can work with two trailers by leaving a full one at the site to nurse the application vehicle, and take the empty one back to the plant. The multi-purpose application vehicle provides the best option for applying sludge to small ownerships.
2. If only one site is being used for applications, there is ample room at the site, and the landowner's concurrence is received, a lagoon at the site may be the most practical and least expensive. Deliveries to the site, then, are not dependent upon application schedule. Generally, this option will require the same equipment as described above. Two trailers may be required, as one would be filling at the plant, while the other would be in transport to the site. Unless there is some storage at the plant, this is a 24-hour, 7-day a week operation.

APPLICATION EQUIPMENT AND OPERATION

Sludge Transfer Equipment

Except with the multi-purpose highway and application vehicle, sludge will need to be moved from an over-the-road vessel to storage and finally to an application vehicle. The two basic transfer mechanisms are direct dumping and pumping, which greatly depend upon the percent solids and the type of storage facility. The percent solids will dictate whether or not transfer operations (i.e., pumping) will be effective, while position and configuration of storage vessels will determine if gravity is sufficient for facilitating transfer.

Direct dumping of sludge is the easiest method of unloading a trailer from a treatment plant. Gravity dumping requires either an in-ground facility, or driving the truck onto a ramp above the storage vessel. Additionally sludge must be dilute enough to flow from the trailer (<8%), dilute enough to flow from a pressurized tank (<15%), or the trailer bed must be elevated.

The ability to pump sludge from a trailer depends upon the percent solids. Below 15%, most sludges will flow as a semi-solid and be able to feed a pump if enough positive head is present or the angle of the trailer bed is great enough. At higher percent solids, bridging of the sludge commonly occurs which will restrict or eliminate flow of sludge to the pump. A centrifugal pump can be used on dilute sludge (<13%), or chopper-type centrifugal pumps may be able to pump up to 15% solids sludge. If a dewatered sludge (>15%) is brought to the site and it is desirable to use a pump to transfer sludge, rewatering and mixing will be required before pumping is possible.

Sludge Application Systems

Four types of forest application methods exist: 1) direct spreading, 2) spray irrigation with either a set system or a traveling gun, 3) spray application by an application vehicle with a spray cannon, and 4) application by a manure-type spreader. The sludge percent solids content is again important to the choice of application systems. Types 1, 2 and 3 are effective for liquid sludge (2-8% solids), Types 1 and 2 can be used for semi-solid sludge (8-18% solids), and only Type 4 is acceptable for solid sludge (20-40% solids). Table 4 lists these types, their range of application, relative costs, and advantages and disadvantages. The method which has been practiced most for forest applications in the Pacific Northwest is by an application vehicle with a mounted cannon.

Many application vehicles have been developed for use in agricultural applications. Most of these can be readily modified for forest use by mounting a spray nozzle and pump on the tank. Application vehicles can also be custom made. Depending on the site needs, a specially designed all-terrain vehicle may be used or, in some cases, a used heavy-duty truck chassis with rear mounted tank has been modified for use. The application vehicle can either be filled via a nurse tanker, directly from on-site storage, or may be a over-the-road multi-purpose vehicle described earlier. Once full, the vehicle moves into the forest over the roads or trails and unloads the sludge in uniform thin layers either while the vehicle is moving or stationary. When empty, the vehicle returns to the sludge source for a refill and repeats the cycle.

Costs for Application

There are many combinations of alternatives available for forest application systems, some of which have been described. The distance to the site and the size of the plant will affect the amount of dewatering desirable, which in turn will play a major role in the interaction of a chosen storage system with transfer and/or application vehicles, and the economic attractiveness of one system relative to another. To-date operation and maintenance cost data is nearly nonexistent because the very few projects currently in operation are still in a research phase or are in a start-up phase (which generally yields inaccurate cost data). Table 4 presents only relative costs for different alternatives.

Table 4: Comparison of Different Application Systems
(Henry *et al.*, 1986).

System and Range	Relative Costs	Advantages	Disadvantages
Sludge spreading and incorporation range = 3 m	Low capital & operations & maintenance	Simple to operate Any % solids	Need cleared site Difficult plantation establishment, some species
Set irrigation system range = 65 m	High capital, low operations & maintenance	Simple to operate	Frequent clogging Use only low % solids; Brush interferes
Traveling big gun range = 65 m	Mod. capital, low operations & maintenance	Simple to operate on appropriate sites	Frequent clogging Use only low % solids; Brush interferes; Need even terrain
Application vehicle with mounted cannon range = 45-65 m	Low-mod capital high operations & maintenance	Any terrain Sludge up to 18% solids	May need special trails
Manure-type spreader range = 50 ft	Low capital & operations & maintenance	Only effective way to apply high % solids sludge	Limited to high % solids, trails close together

Potential Benefits

Potential benefits can be classified in three categories: 1) soil improvement, 2) increased timber production, and 3) secondary benefits from understory vegetation response.

Soil Improvement

As mentioned, the value of sludge is it's ability to amend the soil both by providing nutrients and by improving soil textural characteristics. Both short-term and long-term soil productivity can be improved by sludge additions. There is an immediate supply of virtually every nutrient needed for plant growth in an available form, especially nitrogen. Additionally the fine particles and organics in sludge can immediately and permanently enhance soil moisture and nutrient holding characteristics. In the long-term sludge provides a continual slow release input of nutrients as the organics decompose.

Growth Response

Growth response has also been documented on 60 year old stands (Cole *et al.*, 1984). A six year average diameter growth response of 93% for unthinned and 48% for thinned stands were measured for sludged trees over unsludged trees. Some of the results from a young plantation established on a gravelly outwash soil amended with sludge are shown in Table 5 (Henry and Cole, 1983).

Although the growth response of plantations established in sludge amended soils has been dramatic, survival, as mentioned earlier, is a major problem. Table 5 presents percent mortality for this plantation. It should be noted that some species suffered almost total mortality and would not be recommended for use under these circumstances. Additionally, the problem with plantation establishment has led to the recommendation that, where possible, sludge be applied to existing stands rather than clearcuts.

The accelerated wood growth has led to the concern that wood quality has decreased. A 10 to 15 percent lower specific gravity for the sludge grown wood was found (Cole *et al.*, 1984). This probably reflects the change in forest site quality produced by the sludge treatment and is within the specific gravity range found on higher productivity land.

It is very speculative at this time to estimate the monetary returns from accelerated tree growth for a number of reasons: 1) only a few stands of trees have been measured for growth response, 2) growth responses have only been followed for a short time, i.e., it is not known how long the effect of a sludge application will continue, and 3) benefits have to be estimated many years into the future which depends upon a number of greatly fluctuating factors, such as discount rate and future value of wood. A conservative estimate of the value of sludge could be on the value of the nitrogen fertilizer potential alone, which would be in the neighborhood of \$30 U.S./dry tonne. Preliminary studies, however,

Table 5: Growth Response and Mortality for a Young Plantation
Established in Sludge Amended Soil (Henry and Cole, 1983).

Species	Increase over control		Mortality (%)	
	Height	Diameter	Control	Sludge
Douglas-fir	64%	152%	31	41
W. hemlock	369%	693%	39	99
Sitka spruce	140%	225%	39	49
W. redcedar	65%	114%	61	86
H. cottonwood	590%	893%	37	54
Grand fir	200%	1,250%	17	22
Sequoia	286%	1,033%	0	14

have shown a greater response to sludge than nitrogen fertilizer. Additionally, the effect appears to be much longer lasting, with some studies showing continued growth response eight years after application.

Secondary Benefits

The third type of benefit from sludge additions is much more subjective. Although immediately after application the site is greatly altered in appearance, within six months understory growth is often much more vigorous than prior to application. This is not only visually pleasing, but can be of commercial value to "brush pickers" harvesting ferns and other vegetation for floral arrangements. Increased understory is also typically higher in nutrients and can provide better habitat for wildlife.

STEPS IN IMPLEMENTATION

Three important steps are involved in site planning: 1) finding out the specific requirements of the jurisdictional regulatory agency; 2) identifying and evaluating sites; and 3) receiving public acceptance.

Regulatory

Sludge is classified as a solid waste in the United States, with minimum standards for utilization practices set by Federal legislation in the Clean Water Act, and the Resource Conservation and Recovery Act. As mentioned earlier, U.S. EPA has published a guidance document called Process Design Manual: Land Application of Municipal Sludge (USEPA, 1983). Jurisdictional control of land application practices ultimately are the responsibility of local state environmental agencies, whose policies require varying levels of site investigation and design depending on application rates.

Site Evaluations

The major criteria for site evaluation has been presented in the section on Application Site Characteristics. Both the EPA and state manuals have additional criteria which can aid the designer in appropriate sites and application rates.

Public Acceptance

Research performed throughout the country has proven that environmentally appropriate applications of municipal sludge can be made if properly designed and managed. Quite often, however, the technical or regulatory aspects of sludge applications can be satisfied while lack of public acceptance will stop a project. Sludge, by its nature, raises concerns with many of the public, mainly for the following reasons:

1. It is, of course, derived from human and industrial wastes, and can contain potentially undesirable materials.

2. It can look and smell not entirely desirable.

Because of this there can be a perception problem with many people, and this perception has in turn led to an acceptance problem when evaluating reuse alternatives. "Out of sight, out of mind" does not generally apply to forest/sludge use, since sludge sprayed into existing stands will not be incorporated into the soil. An application of sludge will essentially "paint" the forest floor black, noticeable for a period of 3 to 6 months, depending upon season of application. Sludge adheres to the foliage of trees and understory, but will flake off during the dry season or wash off during the wet season. Also new foliage during the growing season readily covers a sludge "blanket". After a period of one year it is normally difficult to see where a sludge application has occurred, other than a gray tinge on the trunks of trees.

The odor associated with an application will depend upon the amount of stabilization a sludge receives. Normally digested sludge (20-30 day digestion) will have a musty smell which lasts up to 3 months. Odor is more intense in the warm season, but is virtually non-existent if sludge is completely dry, or during cold weather. Most people visiting a site are surprised by the fact that the smell is not offensive.

Many of the questions and perceptions by the public have resulted from a lack of familiarization with constituents and treatment processes involved with wastewater and sludge, and it is therefore very important that a significant amount of energy be spent on educating the public about what sludge is, and the alternatives and potential effects. Public acceptance has been identified by many planners throughout the country as the most difficult part of the planning process for sludge applications. Forest applications are no exception. A recommended approach to public acceptance in the United States is as follows:

1. Make a preliminary evaluation as to the environmental and economic feasibility of an application program.
2. Meet with the health department and public officials and ask them of the general attitude towards reuse options, potential problems and sensitivities, and whether or not vocal groups exist opposing reuse options.
3. Educate the general public. This can be done by public meetings such as low-keyed informational sessions and presentations to community and business groups. We have found that formal public hearings are not always successful. One very successful technique has been to bring people on tours to existing application sites. Additionally, articles from local papers and professional publications are useful.
4. Develop a demonstration project. Following efforts of public education, the attitude of the public towards sludge applications are usually apparent. If the public is generally supportive of the concept, a full-scale

project may be accepted. However, should a large portion of the citizens continue to have major reservations, a demonstration project is often successful. A well designed small-scale project will allow these people to gain an increased comfort level, before being faced with a major project. This is also potentially necessary if sufficient information is not available for a proposed application site.

CONCLUSIONS

Forests should be given serious consideration in the design of any land application program for either municipal or industrial sludge. Research programs conducted in the United States indicate that the sludge can be safely applied to forested sites without compromising public health guidelines. In addition, application of sludge to forested sites can result in an excellent tree growth response with minimal change in the quality of the wood. The technology of both delivering and applying sludge to a forested site has been developed to the extent that many options are now available for most forested terrain.

Because forests are, for the most part, removed from the human food-chain, from a public health perspective they should be more readily accepted for sludge applications than agricultural sites. However, there have been some concerns for the use of forests in this way from the general public. Consequently, to establish a forest sludge application program, it has been essential in the United States to include the public in the planning and design of programs.

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CASCADE CREEK RESTORATION

(A SLIDE PRESENTATION)

H.H. Nesbitt-Porter, P.Eng.

Senior Hydraulic Engineer
Ministry of Environment and Parks
Province of British Columbia

INTRODUCTION

This is essentially a visual tour of a small 25 km² watershed, last glaciated some 10,000 years ago, as seen from the perspective of an engineer charged with the responsibility for bringing about a reasonable degree of protection for residents of the alluvial fan traversed by the lower reaches of Cascade Creek. The principle focus is on aspects which impact significantly on the residential area.

LOCATION

Cascade Creek is situated at the northerly end of the agricultural Hatzic Valley, some 70 km east of Vancouver, B.C., and ranges in elevation from 1360 m down to 100 m GSC where it discharges into Slave Lake. The watershed is comprised of two characteristically different areas; the Upper Watershed and the Lower Watershed.

RECENT HISTORY

Between 1950, when logging of the Upper Watershed commenced, and 1983, some 56% of this area was logged, in addition to which a wide transmission line R/W was cleared and an extensive network of logging and hydro access roads constructed. During clearing of the Hydro R/W in 1974, a slash burning operation got out of control and burnt a further 13% of the Upper Watershed. These various activities together have resulted in effective clearing of about 75% of the area.

Problems in the watershed first became significant in 1977 (Nov. 1) following moderately heavy rains (76 mm/24 hr. at Aggasiz); but during a period when the Nov.-Jan. total precipitation was 55% higher than the 57-year average. The total runoff for the adjacent Norrish Creek was also 55% above its 21-year average during this period.

Many instances of mass wasting, debris torrents and surface scour in the upper areas resulted in massive deposition of gravel and wood debris in the mainstem channel, causing severe damage in the lower, inhabited reach where the channel, choked with gravel at various locations, overflowed its shallow banks.

Subsequent storms during 1982 (Dec.), 1983 (Jan.) and particularly 1984 (Jan.) when 114 mm of precipitation fell in 24 hours at Aggasiz, resulted in recurrences of these problems to varying degrees.

CONSEQUENCES - Upper Watershed

At the higher elevations mass wasting was prevalent throughout much of the area, a direct consequence of the loss of vegetative cover and of access road construction; in one area alone some 12 failures were evident. The width of these erosion scars increases as they progress upslope. This process resulted in extensive outwash deposition at the valley bottom and

downstream bedload movement.

The failure of several towers supporting a high-voltage hydro transmission line across this very steep terrain may also be attributed to disturbance of the soil mantle and loss of the protective vegetation.

CONSEQUENCES - Lower Watershed

In the Lower Watershed the most dramatic and damaging effects were flood flows across the alluvial fan area and infilling of the creek channel with deposited bedload material ranging in gradation from huge boulders near the apex of the fan, below Cascade Creek Falls, to fine sands nearer Stave Lake. This infilling, in addition to increasing the propensity for flooding and channel avulsion, also destroyed any fish spawn and damaged habitat areas.

Property damage included: water damage to buildings and contents, loss of small livestock, damage to access roads and damage to fields by surface scouring, and by the deposition of gravel and floating debris.

REMEDIAL OPTIONS - Upper Watershed

Remedial options in the steep-walled Upper Watershed were generally limited to hydroseeding of road cuts and slide areas using truck-mounted equipment, where possible, or helicopters, but putting redundant access roads "to bed" by regrading the slopes at critical locations, removing drainage culverts and initiating revegetation were preferred, where practical.

Good coverage of exposed mineral soils was generally obtained within two months of seeding.

REMEDIAL OPTIONS - Lower Watershed

On the alluvial fan there were essentially four options for alleviating the flood hazard:

1. periodic channel clearing, either by temporary reshaping using bulldozers, or else by totally removing the deposited material;
2. protection of all or part of the area by dykes, either close to the creek banks, or, preferably, set back from the banks so as to leave a wider floodway and to benefit from the natural protection afforded to the dykes by the intervening trees and vegetation;
3. floodproofing of the existing buildings which would have been very expensive;
4. purchase of affected properties, which would have been even more expensive.

The solution which was ultimately adopted was to build a setback dyke, to provide long-term protection for most of the

area, and to rely on channel excavation, together with a lower standard of dyking, for protection of uninhabited grazing land. Elsewhere, remedial action was limited to the removal and burning of logjams and other forest debris. The existing road bridge was also replaced by a longer one having significant clearance, thus providing adequate capacity for debris-laden flood flows.

CONCLUSION

The lesson to be learned from past experiences in this watershed is that, if detrimental environmental and social consequences are to be avoided, logging and other construction activity in steep West Coast watersheds must be carefully planned and executed so as to minimize disturbance of side slopes, the natural drainage patterns, and the vegetative cover.

REHABILITATION OF NON-PRODUCTIVE FOREST STANDS
IN BRITISH COLUMBIA

Stephen G.J. Homoky

Silviculturist, Rehabilitation
Research Branch, B.C. Ministry of Forests

Jacob Boateng, Ph.D.

Vegetation Management Specialist
Silviculture Branch, B.C. Ministry of Forests

ABSTRACT

The rehabilitation of forest stands that do not support commercial crop vegetation is necessitated by the fact that competing non-crop vegetation suppresses or kills desirable crop species. These stands occupy some of the most productive forest sites. Reforestation failures are the result of intense brush competition and in the absence of some measure of control, these stands will be lost for forest production.

To alleviate the problem, management of non-crop vegetation is mandatory to re-convert these stands to the level of productivity. Otherwise well-established regeneration will become suppressed or the stand will further degenerate to the non-satisfactorily restocked state, increasing backlog.

Vegetation management is also the strategy to address the problem of re-conversion and to release established but suppressed conifer crop regeneration to become free-growing.

This paper discusses the magnitude of the problem, the Ministry Policy to provide the logistical framework, some of the operational techniques, current plans and projections for future planning of vegetation management on Crown Lands.

INTRODUCTION

The total area of old growth forest denuded annually amounts to nearly 200,000 hectares (Cuthbert, 1986). This area must be reforested with acceptable commercial species within a reasonable period of time. Failing to do so, the consequence will be a significant reduction of the future allowable annual cut (AAC). This in turn, can have a detrimental effect on the forest industry and the economy.

Efforts to reforest denuded areas have not always been successful. To a great extent, failure of reforestation is attributed to non-crop vegetation competition especially on the most productive forest lands. Competing vegetation suppress well-established regeneration on some of the valuable growing sites which are classified as brushed-in satisfactorily restocked (SR) areas. Others revert to the level of the non-satisfactorily restocked (NSR) classification, covered by a variety of vegetation complexes. Rehabilitation of these forest stands which occupy productive sites is carried out in the manner of vegetation management. The purpose of vegetation management is the manipulation of non-crop vegetation to assist crop trees to establish and grow freely. Vegetation management is an integral part of the silvicultural process, needed to protect the reforestation investment (Cuthbert, 1986).

The administrative framework to accomplish this task is rooted in the Forest Act (MOF Act, 1979), and the Policy of the Ministry of Forests, (MOF Policy, Site Rehab., 1984). A variety of alternative techniques are available to manipulate non-crop vegetation. The choice depends on the classification of the stand to be treated and the feasibility of the particular technique. Special emphasis is placed on the rehabilitation of non-productive stands in the current five-year forestry program and in the years ahead (MOF, 1984).

THE SCOPE OF THE BRUSH PROBLEM

A sizeable proportion of forest land which was logged or lost to fire, insects and disease is planted, or, where applicable, left to natural regeneration. Reforestation is a joint effort of the Ministry of Forests and the forest industry. At last, the basic planting requirements are closely approaching the projected goals. In 1985, 130 million seedlings were projected to be planted in the province. This figure has been increased to 200 million seedlings for 1987. More than one billion seedlings have been planted on more than one million hectares since 1939 when planting started. The number of seedlings to be planted during the next five years will be only slightly under one billion, according to the recently released Five-Year Forest and Range Resource Program for 1986-1991 (MOF, 1984).

A large proportion of restocked forest land, especially on the most productive sites was invaded by non-crop vegetation. Some valuable land was reduced to the "non-satisfactorily restocked" class, or it degenerated to the "non-commercial brush"

category. This result can be attributed partly to the lack of awareness of and concern about non-crop vegetation and its effects on conifer establishment and development in the past.

Tables 1, 2 and 3 refer to productive sites which were restocked and now are dominated by brush vegetation (Boateng, 1984; Cuthbert, 1986). Figures shown in Tables 1 and 2 are not identical to those in the Forest and Range Resource Analysis. The "NSR" figures in the latter have been reduced because some of the area was restocked since the NSR areas were surveyed. Only gross figures are shown in Tables 1 and 2 as brush problems still may exist even if the areas are considered stocked. Table 1 shows all categories of brush areas on British Columbia crown lands. The priority areas are included in the first four categories, with a total of about 1,061,000 hectares. The Prince George Forest Region contains 56 percent of the total. The backlog and current non-satisfactorily restocked land comprises about 500,000 hectares that require some vegetation control. A total of 237,000 hectares require immediate vegetation management on lands which are not satisfactorily restocked but are brushed-in. In the absence of control, the conifer regeneration will be lost.

If all these brushed-in areas, NSR, NCB_r and SR Brush can be treated, an estimated total of 3.4 million m³ can be gained in allowable annual cut at culmination age. Conversely, if no treatment is applied, 3.4 million m³ is lost from the AAC. The equivalent gain (or loss) for the Prince George Forest Region alone will be 1.5 million m³ annually (Boateng, 1984; Cuthbert, 1986).

In addition to all these losses, approximately 49,000 hectares are added annually to the already existing non-productive problem areas in the province at a rate of 200,000 hectares of annual denudation, if proper vegetation management is not implemented. This figure represents about 25% of the annually denuded area (Boateng, 1984; Cuthbert, 1986).

Deciduous stands of brush areas of British Columbia Crown lands amount to 1.8 million hectares (Table 3). The Prince George Forest Region contains 76 percent of this total. These forest areas are stocked but are either excluded from the AAC calculations or are not utilized to their full potential. Utilization and marketing of deciduous species is expected in the near future. For this reason brush treatment in these stands is not planned (Boateng, 1984; Cuthbert, 1986).

POLICY FOR THE IMPLEMENTATION OF REHABILITATION

The scope and magnitude of the brush problem suggests the necessity of an administrative framework to achieve the desired goals. This framework is provided by the Ministry of Forests Act and Ministry Policy.

Section 4 (a) of the Forest Act (MOF Act, 1979) states that a purpose and function of the Ministry "is to encourage maximum productivity of the forest and range resources in the Province". The Five-Year Forest and Range Resource Program includes the

Table 1: Brush Areas of British Columbia Crown Lands (Good and Medium Sites Only). (Boateng, 1984; Cuthbert, 1986).

BRUSH GROUP	HECTARES
Backlog NSR	342,000
Current NSR	160,000
NC Brush	321,000
Brushed-in SR	237,000
Deciduous	1,140,000
Deciduous/Coniferous	553,000
Coniferous/Deciduous	134,000
Total Area	2,887,000

Abbreviations: NSR = non-satisfactorily restocked
NC = non-commercial
SR = satisfactorily restocked

Table 2: Brush Areas in Hectares: NSR, NC Brush and SR (Crown Lands, Good and Medium Sites) (Boateng, 1984; Cuthbert, 1986)

BRUSH GROUP	PROVINCE	PRINCE GEORGE
NSR	502,250	284,770
NC Brush	321,290	209,480
Brushed-in SR	237,410	94,980
Total	1,060,950	589,320
% of Total		56

Abbreviations: NSR = non-satisfactorily restocked
NC = non-commercial
SR = satisfactorily restocked

Table 3: Areas Covered by Deciduous Vegetation in Hectares
(Crown Lands, Good and Medium Sites) (Boateng, 1984;
Cuthbert, 1986).

GROUP	PROVINCE	PRINCE GEORGE
Deciduous	1,139,890	889,920
Deciduous/Coniferous	553,000	392,230
Coniferous/Deciduous	133,790	109,010
Total	1,826,680	1,391,160
% of Total		76

Table 4: Brushing and Weeding, Conifer Release Five-year
Estimates, in Hectares (Cuthbert, 1986).

YEAR	B & W*	CR*	TOTAL
1985/86	14,000	0	14,000
1986/87	22,000	1,000	23,000
1987/88	32,000	2,000	34,000
1988/89	38,000	3,500	41,500
1989/90	43,000	3,500	46,500
Total	149,000	10,000	159,000

* Includes Forest Renewal Development Agreement

silviculture goals for site rehabilitation (MOF, 1984).

The Ministry Policy (MOF Policy, 1983) statement is as follows:

"Site Rehabilitation will be planned and implemented within the Regions and will be included in Regional Five-Year Forest and Range Resource Programs and budgets under Intensive Silviculture - Site Rehabilitation; whenever economically feasible the on-site material will be utilized; a site rehabilitation plan will be developed for each project, when the proposal is submitted. This Policy Statement provides direction for the planning and implementation of site rehabilitation projects, over conversion stands where commercial values are considered to exist."

For the sake of clarity, certain terms used in this Policy should be defined. "Site Rehabilitation" is the conversion of the existing unsatisfactory cover on highly productive forest sites to a condition appropriate to establishing a crop of commercially valuable species to obtain maximum productivity.

"Conversion Stands" are those stands which are excluded or netted down from the yield analysis and include the following types of forest cover:

- a. Non-commercial brush and weed species
- b. Interior wet belt decadent hemlock-cedar
- c. Interior true fir stands which are poor quality or decadent
- d. Interior and coastal stagnant lodgepole pine stands
- e. Coastal decadent cedar-yellow cedar-hemlock stands
- f. Hardwood stands with or without minor amounts of coniferous species

"Section 52" is a set of provisions under Section 52(a) (MOF Act, 1979) of the Forest Act to increase the Allowable Annual Cut of Forest Licences or major Timber Sale Licences for intensive silviculture treatments carried out by a licensee, in addition to those required under the licence.

"Minor Timber Sale Licence" is a short-term, non-replaceable harvesting agreement.

"Site Rehabilitation Plan" is a schedule of proposed treatments including cost estimates which must be developed for any rehabilitation project from removal of existing cover to the establishment of desired species and successful attainment of "free growing" condition. Trafficability, soils, ecological capability, etc., are all accounted for in treatment plans.

Three conditions are applicable to this Policy:

- a) First consideration is given to areas that do not contain timber that can be utilized.
- b) Projects should be not less than 10 hectares in size, to complement future forest management regimes.
- c) The possibility of future use of on-site material will

not preclude the consideration of projects.

Responsibilities to administer this Policy are divided, according to their functions, between the Directors of the Silviculture and Timber Management Branches, Regional Managers and District Managers. Procedures of the administration of this Policy are specified for Timber Supply Areas according to four stand conditions and for Tree Farm Licences according to three stand conditions. Stand conditions are defined by the value of recoverable timber, such as:

- a) no timber values
- b) minor values, uneconomical to harvest
- c) economics of harvesting are uncertain
- d) substantial timber values, such as (b), (c) and (e) types of conversion stands, listed previously.

Present and Future Plans

Forest vegetation management is given special attention in the current five-year forestry program and in the years ahead. Past experiences suggest that vegetation management must be an integral part of the silvicultural process in order to secure future wood supplies. In every problem treatment, the most logical and effective approach is the prevention of escalation of existing difficulties to costly or unmanageable proportions. To manage the brush problem effectively, the first stage is to improve stand establishment procedures that reduce brush encroachment and increase the growth of crop trees (Cuthbert, 1986). The initial fast development of crop trees is enhanced when the sites are well prepared and planted with large, vigorous stock, but brushing and weeding will always remain an integral part of stand management.

Current brushing and weeding and conifer release activities will be increased by 330 percent by the end of this decade. The estimated increases are shown in Table 4 (Cuthbert, 1986). A total of 159,000 hectares to be treated is projected by the end of the five-year period, ending in 1990. This increase of brushing and weeding activities will be made possible by the recently announced forest stand management funds.

Table 5 (Cuthbert, 1986) indicates that brushing and weeding and conifer release will be more than half of major stand tending activities. Additional vegetation management is expected to materialize in association with other silvicultural activities.

The total five-year goals for site preparation and rehabilitation are 625,000 hectares and 171,200 hectares, respectively, as shown in Table 6 (Cuthbert, 1986).

PROCEDURES AND TECHNIQUES FOR REHABILITATION

The actual field operation of rehabilitation is carried out in four phases, based on cruise information data, following a planning proposal and an operational proposal of the rehabilitation project. The planning proposal contains the

Table 5: Major Stand Tending Activities; Five-year Total
(1985-90) (Cuthbert, 1986)

ACTIVITY	HECTARES	PERCENT
B & W/CR	159,000	53.2
Fertilization	79,000	26.4
Spacing	61,000	20.4
Total	299,000	100.0

Abbreviations: B & W = brushing and weeding
CR = conifer release

Table 6: Site Preparation - Site Rehabilitation; Five-year
Estimates, in Hectares (Cuthbert, 1986).

YEAR	SITE PREPARATION	SITE REHABILITATION
1985/86	110,000	20,000
1986/87	125,000	37,800
1987/88	130,000	37,800
1988/89	130,000	37,800
1989/90	130,000	37,800
Total	625,000	171,200

description of interpretations information and it aids in the construction of a regeneration plan specifying the operations. It also includes pertinent maps, communication records with the Regional Pedologist and the inputs from Ministry Branches and agencies. The operational proposal, referring to Sections 52 and 88 of the Forest Act, has input from the Timber Management, Protection, Engineering and Silviculture Branches. It includes the synopsis and Cut Incentive Calculations. Based on cruise information that determines the "site condition" of the area to be rehabilitated (reference is made to Ministry Policy, Procedures, Chapter: SIL, Section 005), the four phases of rehabilitation are specified:

1. Slashing and/or logging phase. Standing trees are felled and the salvageable material, if any, is extracted.
2. Herbicide/or mechanical brush removal phase. Depending on access, trafficability or other pertinent characteristics of the site, mechanical or chemical technique is employed. If herbicides are used, this phase is also termed as the "spraying" or "browning phase". Other chemical application methods include stem injection (hack-and-squirt) and stump injection. As an alternative to herbicides, mechanical site preparation techniques can be used to remove slash and vegetation. Mechanical site preparation can be achieved either with tractor-mounted special bulldozer blades, disc trenchers or cultivators with tined wheels, for instance, the Bracke Cultivator and the Leno Scarifier. The essential requirement for brush control is the ability of the machinery to uproot the brush vegetation. Simple cutting of the plant above ground level does not accomplish the desired results as the plant can re-sprout after cutting. The choice between mechanical site preparation and other site preparation methods is dictated by the technical feasibility, terrain and soil conditions and associated operating costs.
3. Burning phase. Slash and foliar-killed shrubs are disposed of in the process of a controlled burn to create a plantable site.
4. Planting phase. The prepared site is replanted with large, vigorous stock. Heavy stock type on rehabilitated good and medium growing sites is mandatory to ensure fast seedling growth and the ability of the planted tree to compete with subsequent encroachment of brush vegetation. Contrary to widespread belief, herbicides do not kill all vegetation forever, therefore on most productive forest sites a second pass of herbicide application may be required within a year or two, in order to release developing regeneration from competition. The aim is to assist the planted trees to reach the free-growing stage. The silvicultural process however, continues in the form of conifer release, juvenile spacing, and if applicable, commercial thinning.

THE COST OF STAND REHABILITATION

The cost of operations ranges from \$200 to \$500 per hectare but it can increase to as much as \$1,000 per hectare depending on the method used, the difficulty of the terrain and the severity of the brush problem.

Summarized data provided by the Silviculture Branch in 1986 suggest that provincial cost-per-hectare figures decreased as a result of experience, improved techniques and increase in the size of the area treated. During the 1981/82 period only \$261 was spent per hectare on 3,087 hectares. During the subsequent two year period, 1982/83 and 1983/84, treated areas totalled 2,782 and 1,792 hectares only, with increased average costs of \$457 and \$409 per hectare, respectively. By the 1984/85 period a total of 14,493 hectares were treated with a corresponding average cost of \$280 per hectare.

CONCLUSION

The restoration of the brushed-in good and medium forest sites to their former level to support productive forest stands is an indispensable component of silviculture. Logged and burned areas or those damaged by disease and insect attacks which are now overgrown with non-crop vegetation cannot contribute to wood production unless vegetation management is implemented. The current and backlog "non-satisfactorily restocked" stands should be converted to the "satisfactorily restocked" classification. Those areas which have already been satisfactorily restocked but the coniferous regeneration is suppressed by heavy competition must be treated by conifer-release techniques.

The numbers presented in Tables 4, 5 and 6 suggest that the stand rehabilitation program is a formidable undertaking. Knowledge and experience are required to accomplish the projected goals. Continued and sustained joint support is needed from decision-makers at the Federal and Provincial levels of government and the forest industry. Fish and wildlife biologists, ranchers, equipment and chemical manufacturers and educational institutions must co-operate with foresters. All this demands a lot of money but long-range silvicultural programs can be sustained only with continued funding.

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REHABILITATION OF DEGRADED FOREST SOIL IN THE
PRINCE GEORGE FOREST REGION

A.J. McLeod

Regional Pedologist
B.C. Ministry of Forests, Prince George

W. Carr

Consultant, Terrasol
North Vancouver

The Prince George Forest Region is the largest of the six forest regions in British Columbia with a total forested landbase comprising 17,718,000 ha or 38% of the overall forested landbase of British Columbia.

Each year there is approximately 57,000 ha logged in this region mainly using the clearcut harvesting system. Studies have shown that 18% of this harvested landbase is affected adversely by a combination of landings, main road and skid trail development (McLeod and Hoffmann, 1984). Landings were found to comprise 4% of the harvested landbase. Thus 2,280 ha/year are being affected by landings in the region (8,657 ha/year on a provincial basis).

Compaction levels on these landings average about 1.5 Mg/m^3 , indicating that severe soil compaction is occurring on these landings (McLeod, 1983).

Managers are divided in their opinions that either,

- a) unrehabilitated landings are capable of growing a commercial tree thus these areas can be retained in the landbase used to calculate the Allowable Annual Cut or,
- b) landings are capable of growing a commercial tree only if landing rehabilitation efforts are initiated.

Regardless of which opinion is valid, the fact remains that failure to maintain these areas as part of the productive forested landbase could result in the reduction of the Allowable Annual Cut available for the forest industry in the region.

Concerns were raised from various quarters that landing rehabilitation would not be successful at a reasonable cost so an ad-hoc committee was struck, whose objective was to develop a realistic landing rehabilitation standard operating procedure which would be adhered to by the forest industry in the region. Below is a portion of the standard operating procedure (S.O.P. 2-1) for landing rehabilitation, issued by the Ministry of Forests, Prince George Forest Region. The intent of this standard operating procedure is to provide a basis for site specific decision making to ensure:

- a) that the productive capability of Crown Forest and Range land is maintained.
- b) that the total disturbance by landings is minimized.
- c) that the location, construction and operation on a landing facilitates its rehabilitation.
- d) that fire hazards, fire hangovers and habitat for bark beetle brood development is minimized.
- e) that landings are satisfactorily revegetated.
- f) that "best opportunity" landings are fully rehabilitated

and reforested with coniferous trees. Best opportunity for the purposes of this standard operating procedure is defined as landings located on flat to rolling terrain, with light to moderate coarse fragments, on moderate to high site ecosystems and not over 100 kilometers away from the conversion facilities.

In order to ensure that the intent of this standard operating procedure is being complied with, seven procedures were developed. These procedures outline what the British Columbia Ministry of Forests, Prince George Forest Region expects industry to adhere to when any landing developments are being initiated. The seven procedures are:

1) Approval

An application for a cutting permit under a harvesting agreement shall include specific details on:

- a) the number, dimensions and location of all landings for each cutblock.
- b) debris disposal on all landings.
- c) rehabilitation category and methods to be employed.
- d) erosion control (where required).
- e) revegetation plan

No on-site work is to be undertaken until the logging plan is approved by the District Manager.

2) Number and Size

The area disturbed for landings shall not normally exceed 3.5% of the total area of the cutblock, except as may otherwise be approved by the District Manager in consideration of special circumstances.

3) Location

Wherever possible and practical landings shall be a minimum of 40 meters from all cutblock edges, immature timber, lakes, swamps, streams and water courses and from open natural range.

4) Construction

Stumps shall be up-rooted and moved with the least amount of soil. They shall be placed around the periphery of the landing or disposed of with other combustible material.

All combustible debris from the cleared portion of the landing shall be placed in a concentrated cull pile within the confines of the landings. Except for those areas scheduled for broadcast burning, burning permits will not be issued until this requirement is satisfied.

The burying of stumps will only be permitted where in the Pre-harvest Silviculture Prescription the landing is deemed to be Category 1 and the objective is to not grow a future crop of commercial conifer trees.

5) Operations

The cull pile shall contain a minimum accumulation of soil and shall be located so that it is readily accessible for resspreading after burning.

All combustible debris which accumulates on the landing shall be placed in the cull pile.

The cull pile shall be surrounded by a mineral soil guard except where the cutblock will be broadcast burned.

6) Slash Disposal

Burning of the cull pile shall be required on all landings and shall be the only approved method of treatment.

All burning shall be carried out in accordance with the District Managers instruction letter and burning permit.

The majority of the combustible debris must be consumed by burning. The level of disposal must be consistent with objectives regarding:

- a) reduction of hazard.
- b) elimination of hangover fires.
- c) bark beetle control.
- d) optimizing grazing potential.
- e) landing revegetation.
- f) recreational and aesthetic values.

7) Rehabilitation

Three separate levels or categories of rehabilitation have been established. Decisions for identifying landing rehabilitation category will be made at the Pre-Harvest Silvicultural Assessment stage but may be fine-tuned after logging.

The category of rehabilitation will be as identified in the appropriate field guide when these are next revised. The actual identifying and interpreting which ecosystem the manager is dealing with and the appropriate category of landing rehabilitation that will be required as a result of this information is in an appendix attached to the standard operating procedure but it is not included in this paper.

For the present where the ecosystem classification has not yet been completed, Category 3 (full rehabilitation) will be carried out on all good and medium sites except where:

- a) coarse fragments exceed 30%, or
- b) where summer access is impossible, or
- c) where slope (where landing occurs) exceeds 30%.

Category 1 - No rehabilitation

The objective will be hazard abatement and any necessary erosion control. The following conditions must be complied with:

- a) all woody material must be thoroughly burned
- b) construction of waterbars, as required.

Category 2 - Partial rehabilitation

The objective is the same as Category 1 but in addition there is a prime consideration for an aspect other than the growing of a crop of trees (erosion, aesthetics, range and wildlife, etc.). The following conditions must be complied with:

- a) requirements of Category 1
- b) spread residual ash and remaining woody debris uniformly over the landing area.
- c) seed with an inoculated legume (100% alsike) or forest rangeland mix if Range/Wildlife consideration.

Category 3 - Full rehabilitation

The objective is to grow a future crop of commercial conifer trees which may coincidentally provide consideration for other forest resource values. The following conditions must be complied with:

- a) requirements of Category 1
- b) after burning all residual ash and debris must be uniformly spread over the landing area.
- c) ripping of landing now required as follows:

All soil types with up to 30% coarse fragments

Rip with a winged subsoiler to a depth of 1 meter. Specialized pull type equipment should be used. In a second pass, mix in any available ash, topsoil, organic debris with discing type device to a depth of at least 30 centimeters. Work should only be done under conditions of moderate soil moisture.

- d) seed with an inoculated legume (100% alsike) if there is range use potential this should be considered in the type of mix.
- e) all Category 3 rehabilitated landings should be planted to Lodgepole pine, preferably one year after seeding.
- f) a slow release fertilizer material should be utilized with each seedling planted on a rehabilitated landing to encourage initial growth response.

Concurrent to the implementation of this standard operating procedure, three projects were initiated in the region to further study what status unrehabilitated and rehabilitated landings were

in. The studies initiated were:

- a) Historical survey of unrehabilitated landings (McLeod and Carr, 1986).
- b) Assessment of landing rehabilitation activities in the Prince George East Forest District (Carr and McLeod, 1986).
- c) Evaluation of ripping effectiveness of a winged subsoiler for soil decompaction in the Prince George Forest Region (Carr and McLeod, 1986).

The historical survey indicated that the nutrient pools were very poor on unrehabilitated landings, foliar levels of N, P and K were very deficient for both ³Lodgepole pine and white spruce, and compaction averaged 1.4 Mg/m³ or greater regardless of summer or winter construction.

The results of the assessment of landing rehabilitation activities in the Prince George East Forest District, indicated that the rock ripper failed to produce the desired tillage results on either coarse or fine textured landings. The maximum depth of ripping (approximately 17 cm) and the percent of the profile affected (approximately 26%) are far from the desired 30 cm ripping depth and 80 - 100% profile shatter. Even though there was some degree of tillage, there was no significant impact on soil density levels. The lack of soil organic matter has contributed to a reconsolidation of both fine and coarse textured soils. No soils treated possessed the desired well aggregated structure that enhances soil aeration, moisture, and temperature regimes. Even if the ripping operation had successfully achieved the desired effects, forest productivity on the landings would still be greatly impaired by a lack of soil nitrogen, phosphorus, and potassium. On all landings studied, the residual soil concentration of nitrogen, phosphorus, and potassium do not meet the minimum levels for commercial pine establishment as recommended by Monenco (1983).

The results of the winged subsoiler indicated that the winged subsoiler easily accomplished two of the trial objectives, reducing soil density and ripping an average of 30 cm in depth. The degree of profile shatter in Prince George exceeded the results from Oregon (137% versus 80%, respectively) and was vastly superior to results in Prince George obtained using the rock ripper (26%) (Carr and McLeod, 1986). However, problems with soil reconsolidation still occur and can offset any gains from tillage.

As a result of these studies the region has decided to enforce procedure 1 through 6 but opt for operational research trials for procedure 7. A contract has been let to have a winged subsoiler built in Prince George and made available to the forest industry to use. Currently the region is working with the forest industry to set up a good distribution of rehabilitated landings which could be assessed over time to develop a permanent, comprehensive data set to answer the question of whether or not landing rehabilitation is possible on the types of soils present in the region. Initially physical data such as nutrient pool and soil physical properties can be monitored to determine if the

rehabilitation effort is working, but over time the seedlings planted on these sites will also begin showing managers if they can obtain acceptable growth and appropriate piece size. Further research will continue on this important aspect of forest management. Failure to successfully rehabilitate these areas will only result in significant changes to the Allowable Annual Cut or to harvesting methods currently utilized by the forest industry in the Region. No matter how you look at it, additional costs associated with maintaining the productive landbase will need to be borne by the forest industry in order to keep in business.

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REVEGETATION AND RECLAMATION OF ASH LAGOON SURFACES
IN CENTRAL ALBERTA

Thomas A. Oddie
Monenco Consultants Ltd.
Calgary, Alberta

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ABSTRACT

A number of experiments were initiated near Wabamun, Alberta to investigate methods of stabilizing ash lagoon surfaces, using revegetation and reclamation techniques, at coal-burning thermal power plants. The coal ash constitutes a poor plant growth medium since it is deficient in organic matter and many plant nutrients, contains potentially phytotoxic levels of boron, has a high pH, no ion exchange complex and is easily eroded when dry. A bulk ameliorant trial was established to determine revegetation success of a forage mixture seeded on an ash lagoon surface using several topsoil, minespoil and manure treatments. Results showed that all capped treatments produced a more dense plant cover than bare ash. Manure was the most effective amendment for improving forage yields. A mulch trial was initiated to determine the effects of surface straw mulch or cultivated straw mulch treatments on forage establishment and growth. Straw mulch treatments did not significantly increase plant cover and forage yields compared to the bare ash control and inhibited seedling development on surface straw mulch treatments. A legume trial was used to test the establishment, growth and nitrogen fixing capability of several legume species seeded on bare ash. Overall, the alfalfa, sweetclover (biennial) and birdsfoot trefoil legume species were easiest to establish, produced higher yields and fixed more nitrogen than cicer milkvetch and red clover.

INTRODUCTION

The Wabamun thermal power generating station is located approximately 65 km west of Edmonton in Central Alberta. After strip-mined coal is burned at the station, about 15% of the original material remains as silicious, non-carbon or non-combustible ash material. Fly ash is airborne particulate matter removed from the boiler flue gas emissions, while bottom ash is solid residual material accumulating in the bottom of the furnaces. At Wabamun, approximately 2 million tonnes of coal from the Whitewood Mine are burned annually, producing approximately 300,000 tonnes of ash material. Waste ash material is often removed from the plant by mixing it with water to form a slurry and pumping it through a pipeline to disposal lagoons in the vicinity of the station. The ash settles and water is removed until the lagoon is full, presenting a flat expanse of unstable, unaggregated, sand sized material. Unless steps are taken to stabilize the exposed ash surface, the material is highly susceptible to wind transport and dusting.

Revegetation is a common method of surface stabilization, but ash lagoons provide a hostile environment for plant growth. Desirable plant growth qualities are limited to factors such as the flat surface which reduces water erosion, the sandy loam texture which provides good drainage and easy root/shoot penetration, and a lack of salinity or sodium toxicity problems. Undesirable qualities include a strongly alkaline pH, phytotoxic levels of micronutrients such as boron, a lack of an organic fraction and micro-organisms, a very small cation exchange capacity and few plant nutrients (Burton *et al.*, 1982; Hodgson and Townsend, 1973; Monenco Limited, 1986; Ziemkiewicz *et al.*, 1981). Unless or until pozzuolanic cementation occurs, as a result of the cohesion of the carbonate coatings of the ash particles, the material is highly unstable, easily moved by wind and has low bearing strength. Experimental trials were initiated to investigate methods of dealing with undesirable ash characteristics.

BULK AMELIORANT TRIALS

The bulk ameliorant trials were initiated to determine the revegetation success of an agricultural forage mixture seeded on an ash surface using several topsoil, minespoil and manure capping treatments. A Gray Luvisol topsoil, non-sodic minespoil and barnyard manure were selected from locally available stockpiles. All three maintain some potential to improve fertility, lower pH, increase cation exchange capacity, reduce micronutrient phytotoxicity and increase microbial activity in an otherwise sterile ash growth medium.

Methods and Materials

Plots were established in 1977 when all possible combinations of topsoil (8 cm), minespoil (8 cm) and manure (8 cm) capping treatments were applied to an ash lagoon surface and cultivated to a depth of 15 cm. A fertilizer-only and unfertilized control were

included and all treatments were replicated twice. The experimental area was broadcast seeded with a forage mixture containing *Bromus inermis* (Smooth brome grass - 20 kg/ha), *Agropyron cristatum* (Crested wheatgrass - 12 kg/ha), *Festuca rubra* spp. *rubra* (Creeping red fescue - 4 kg/ha) and *Medicago sativa* (Common alfalfa - 4 kg/ha). Maintenance applications of fertilizer (N-P-K-S) were applied each year to all plots except the unfertilized control. The central portion (1m x 5m) of each sub-plot was used for experimental measurement of plant cover, forage yield and ash chemistry. Statistical analysis of data was completed using the Statistical Analysis System (S.A.S. Institute, 1985).

Results and Discussion

Analysis of plant cover data collected over 5 years showed that all capping treatments had significantly more total plant cover than the fertilized and unfertilized controls (Table 1). Capped treatments and controls consisted mostly of *Bromus inermis* (Smooth brome grass), *Festuca rubra* spp. *rubra* (Creeping red fescue) and lesser amounts of *Poa compressa* (Canada bluegrass) and *Agropyron repens* (Quackgrass). Creeping red fescue and Canada bluegrass are known for their tolerance to low fertility and drought, while smooth brome grass and quackgrass are very aggressive species, adaptable to a wide variety of growth conditions.

As was expected, harvest data showed that all cap treatments containing manure, including the manure-only (463 g/m²), manure + topsoil (443 g/m²), manure + minespoil (428 g/m²) and manure + topsoil + minespoil (477 g/m²) treatments, yielded significantly more plant biomass than all other treatments and controls. All remaining cap treatments, including the topsoil-only (297 g/m²), minespoil-only (298 g/m²) and topsoil + minespoil (291 g/m²) treatments, yielded more plant biomass than the fertilized and unfertilized controls. Although better plant growth was expected on topsoil than minespoil, no difference in yield measurements were observed. The fertilized (173 g/m²) and unfertilized (164 g/m²) controls yielded the significantly lowest amount of plant biomass, but were not significantly different from each other. Applications of fertilizer on seeded bare ash were not enough to significantly improve revegetation success, indicating that poor fertility is just one of many deficiencies in ash material.

Soil pH (0-15 cm) was significantly lower in all capped treatments than the fertilized and unfertilized controls. Levels of organic carbon (0-15 cm) were significantly lower in the fertilized and unfertilized controls than in all the capped treatments. Very low carbon levels demonstrate that bare ash is essentially sterile, contains no organic matter, few micro- and macro-organisms and has very low rates of carbon accumulation. The observed available boron levels in the ash (0-15 cm) range from 2.9-8.6 µg/g. Boron levels can be rated as slightly toxic to tolerant to plant species when ash levels range from 4-10 µg/g (Hodgson and Townsend, 1973). The manure + topsoil treatment had significantly higher available boron levels than all remaining capped treatments and controls, but were not directly attributable

TABLE 1

Bulk Ameliorant Trials
Relationship Between Single Treatments and Plant Biomass, Cover and
Ash Chemistry Over All Years (1978 - 1985)

Treatments	Manure Only	Topsoil Only	Minespoll Only	Manure plus Topsoil	Manure plus Minespoll	Topsoil plus Minespoll	Manure, Topsoil and Minespoll	Fertilizer Only	Untreated Control
Biomass (g/m²)									
Mean $\pm$ S.D.	463 $\pm$ 163	297 $\pm$ 192	298 $\pm$ 202	443 $\pm$ 111	428 $\pm$ 153	291 $\pm$ 148	477 $\pm$ 192	173 $\pm$ 88	164 $\pm$ 141
Grouping ^a	a	b	b	a	a	b	a	c	c
Total Cover (%)									
Mean $\pm$ S.D.	102 $\pm$ 10	110 $\pm$ 27	98 $\pm$ 13	115 $\pm$ 28	118 $\pm$ 29	120 $\pm$ 32	109 $\pm$ 27	68 $\pm$ 32	63 $\pm$ 32
Grouping ^a	bc	ab	c	a	a	a	abc	d	d
pH (0-15 cm)									
Mean $\pm$ S.D.	7.3 $\pm$ 0.3	7.5 $\pm$ 0.3	7.4 $\pm$ 0.2	7.0 $\pm$ 0.3	7.2 $\pm$ 0.3	7.2 $\pm$ 0.2	7.1 $\pm$ 0.2	7.8 $\pm$ 0.3	8.0 $\pm$ 0.4
Grouping ^a	bcd	b	bc	d	bcd	bcd	cd	a	a
Total N (0-15 cm)									
Mean $\pm$ S.D. (ug/g)	1933 $\pm$ 882	1155 $\pm$ 560	868 $\pm$ 284	2775 $\pm$ 223	1406 $\pm$ 249	952 $\pm$ 909	2810 $\pm$ 1373	286 $\pm$ 105	238 $\pm$ 25
Grouping ^a	b	bcd	cde	a	bc	cde	a	de	e
Organic C (0-15 cm)									
Mean $\pm$ S.D. (%)	2.5 $\pm$ 1.0	2.0 $\pm$ 1.0	2.2 $\pm$ 1.1	4.1 $\pm$ 0.3	2.8 $\pm$ 0.9	3.2 $\pm$ 0.4	3.9 $\pm$ 2.4	0.6 $\pm$ 0.1	0.7 $\pm$ 0.1
Grouping ^a	c	c	c	a	bc	abc	ab	d	d
Available B (0-15 cm)									
Mean $\pm$ S.D. (ug/g)	6.3 $\pm$ 5.5	3.9 $\pm$ 0.9	2.9 $\pm$ 0.9	8.6 $\pm$ 7.8	3.3 $\pm$ 1.1	5.2 $\pm$ 5.6	4.2 $\pm$ 2.0	3.2 $\pm$ 0.9	4.1 $\pm$ 3.4
Grouping ^a	b	de	e	a	de	bc	cd	de	d

S.D. = Standard Deviation

a = Results of Duncan's multiple range test. Means with the same letter are not significantly different (P = 0.05).

to either pH or organic matter content. Total nitrogen (0-15 cm) was significantly higher in the manure + topsoil and manure + topsoil + minespoil treatments than in all remaining treatments and controls, likely due to the presence of both manure and topsoil.

Conclusions

1. All capping treatments (manure, minespoil, topsoil), alone or in combination, produced more plant cover and forage biomass than the uncapped ash controls.
2. Applications of fertilizer alone did not significantly improve crop growth on seeded bare ash.
3. Manure appeared to be the most effective capping treatment for improving yields.
4. All capping treatments reduced pH levels from those observed on the bare ash.
5. All capping treatments were successful in improving organic carbon levels over the low levels found in bare ash. Untreated ash contains no organic matter, few (if any) micro/macro-organisms and has very low rates of carbon accumulation.
6. Available boron levels were rated as slightly phytotoxic to plant growth. The manure and topsoil treatment had the highest available boron levels but were not directly attributable to either pH or organic matter content.

STRAW MULCH TRIALS

The mulch trials were initiated to determine the effects of cultivated and uncultivated surface straw-mulch treatments on forage establishment and growth on an ash lagoon surface. Straw mulch was selected as an ash treatment due to its local availability and use as an agricultural soil amendment. Organic matter additions like straw, domestic sewage, peat, animal manure and other harvest wastes can help improve soil fertility, cation exchange capacity, soil aeration, water holding capacity, microbial activity and reduce phytotoxic concentrations of micronutrients.

Methods and Materials

Plots were established in 1979 when straw mulch₂ was applied to an ash lagoon surface at a rate of 1.7 kg/m². Cultivated treatments were rototilled to a depth of 15 cm while uncultivated treatments were covered with fish-netting to hold straw in place. A fertilizer-only control was included and all treatments were replicated three times.

All plots were seeded to a forage seed mix of *Agropyron trachycaulum* (Slender wheatgrass - 13 kg/ha), *Festuca rubra* spp. *rubra* (Creeping red fescue - 12 kg/ha), *Bromus inermis* (Smooth

bromegrass - 12 kg/ha), *Phleum pratense* (Timothy - 7 kg/ha), *Trifolium pratense* (Red clover - 2 kg/ha), *Trifolium hybridum* (Alsike clover - 2 kg/ha) and *Medicago sativa* (Common alfalfa - 2 kg/ha) using a hand broadcast applicator. Maintenance applications of fertilizer (N-P-K-S) were applied each year. The central portion (1m x 2m) of each sub-plot was used for experimental measurement of plant cover, forage yield and ash chemistry. Statistical analysis was carried out using the Statistical Analysis System (S.A.S. Institute, 1985).

Results and Discussion

The cultivated mulch treatment (94%) and untreated control (96%) both had significantly more plant cover of seeded species than the uncultivated mulch treatment (78%) (Table 2). Non-vegetated patches of surface straw on the uncultivated mulch treatment, as well as some volunteer species growth, accounted for this difference. The surface straw appeared to create an environment too cool and dark for successful seedling establishment. Vegetation on all plots consisted largely of *Medicago sativa* (Common alfalfa), *Bromus inermis* (Smooth bromegrass) and *Festuca rubra* spp. *rubra* (Creeping red fescue) as well as small amounts of *Phleum pratense* (Timothy).

Analysis of harvest data showed that forage yields from the cultivated surface straw mulch treatment (448 g/m²) and untreated control (431 g/m²) were not significantly different from each other, but were significantly higher than the yields from the uncultivated surface straw mulch treatment (305 g/m²).

The requirement for available nitrogen by forage crops grown on normal agricultural soil has been described as deficient from 0-10 µg/g, marginal from 10-25 µg/g and adequate from 25-38 + (Carsen, 1986). In comparison, levels of available nitrogen (0-15 cm) in the ash appear deficient across all treatments. Available nitrogen was significantly higher in the cultivated surface straw mulch treatment than in the uncultivated surface straw mulch treatment and fertilized control. This suggests a possible increase in ash available nitrogen due to decomposition of incorporated straw mulch.

The observed available boron levels in the ash (0-15 cm) ranged from 4.3 - 6.6 µg/g. Boron levels can be rated as slightly phytotoxic to tolerant to plant species when ash levels range from 4-10 µg/g (Hodgson and Townsend, 1973). Available boron was significantly lower in both straw mulch treatments compared to the fertilized control.

Conclusions

1. Straw mulch treatments did not improve plant cover and forage production compared to seeded bare ash. In fact, the uncultivated surface straw mulch treatment had less plant cover and forage biomass than the bare ash control. The surface mulch appears to create an environment too cool and dark for successful seedling establishment.

TABLE 2

Straw Mulch Trials
Relationship Between Single Treatments and Plant Biomass, Cover and
Ash Chemistry Over All Crop Years (1980 - 1985)

Variable	Treatment		
	Uncultivated Surface Straw Mulch	Cultivated Surface Straw Mulch	Fertilized Control
<u>Biomass (g/m²)</u>			
Mean $\pm$ S.D.	305 $\pm$ 165	448 $\pm$ 178	431 $\pm$ 184
Grouping ^a	b	a	a
<u>Seeded Cover (%)</u>			
Mean $\pm$ S.D.	78 $\pm$ 27	94 $\pm$ 16	96 $\pm$ 10
Grouping ^a	b	a	a
<u>Available N (0-15 cm)</u>			
Mean $\pm$ S.D. (ug/g)	3.7 $\pm$ 3.9	9.6 $\pm$ 9.4	5.6 $\pm$ 5.3
Grouping ^a	b	a	b
<u>Boron (0-15 cm)</u>			
Mean $\pm$ S.D. (ug/g)	4.3 $\pm$ 2.0	4.3 $\pm$ 1.6	6.6 $\pm$ 2.5
Grouping ^a	b	b	a

S.D. = Standard Deviation

a = Results of Duncan's multiple range test. Means with the same letter are not significantly different (P = 0.05).

2. Available plant nitrogen was deficient across all treatments, but was highest in the cultivated straw mulch treatment. Nutrient reserves appear to be depleting over time through plant uptake and leaching, while the limited number of ash micro-organisms appears to limit the rate of mulch decomposition.
3. Both straw mulch treatments had less available boron than the bare ash control, possibly due to an interaction between boron and the organic matter fraction.

LEGUME TRIALS

The legume trials were initiated to determine the establishment, growth and nitrogen fixing capabilities of several agricultural legume species grown on bare ash. Major plant nutrients, especially nitrogen, are vital for sustaining healthy plant growth. Legumes can provide their own organic source of nitrogen by fixing atmospheric nitrogen through a specialized bacterial symbiosis in legume root nodules. Since ash is deficient in major plant nutrients, the use of legumes in revegetation programs appears critical in obtaining long-term reclamation success.

Methods and Materials

Plots were established in 1980 and 1983 when several common agricultural legume species were broadcast seeded and packed onto an ash lagoon surface. Pre-inoculated seed treatments included *Medicago sativa* (Common alfalfa - 20 kg/ha), *Melilotus alba* (White sweetclover - 40 kg/ha), *Astragalus cicer* (Cicer milkvetch - 60 kg/ha), *Lotus corniculatus* (Birdsfoot trefoil - 20 kg/ha) and *Trifolium pratense* (Red clover - 40 kg/ha), as well as a *Festuca rubra* spp. *rubra* grass control (Creeping red fescue - 40 kg/ha), and an unseeded control. All treatments were replicated four times in a randomized block. Maintenance applications of fertilizer (P-K-S) were applied each year. The central portion (1m x 2m) of each sub-plot was used for experimental measurement of plant cover, forage yield and ash chemistry. Statistical analysis was carried out using the Statistical Analysis System (S.A.S. Institute, 1985).

Results and Discussion

The sweet clover (71%), alfalfa (70%) and creeping red fescue (63%) had significantly more plant cover of seeded species than the other legumes and controls (Table 3). Cicer milkvetch (38%) and birdsfoot trefoil (31%) had significantly more seeded plant cover than the red clover (17%). The birdsfoot trefoil, cicer milkvetch, red clover and unseeded control contained notably more volunteer species than the alfalfa, sweet clover and creeping red fescue. The alfalfa had very few weeds, once established, and the unseeded control had a considerable amount of volunteer legume growth from adjacent plots.

Harvest data from each three year program showed alfalfa (508 g/m²) yielding significantly more plant biomass than all other

TABLE 3

Legume Trials
Relationship Between Single Treatments and Plant Biomass, Cover and
Ash Chemistry Over All Established Crop Years

Treatment	Alfalfa	Birdsfoot Trefoli	Cicer Milk Vetch	Red Clover	Sweetclover	Grass Control	Unseeded Control
Biomass (g/m²)							
Mean $\pm$ S.D.	508 $\pm$ 136	286 $\pm$ 127	234 $\pm$ 134	171 $\pm$ 128	313 $\pm$ 213	46 $\pm$ 59	123 $\pm$ 105
Grouping ^a	a	b	bc	cd	b	a	de
Seeded Cover (%)							
Mean $\pm$ S.D.	70 $\pm$ 21	31 $\pm$ 22	38 $\pm$ 17	17 $\pm$ 25	71 $\pm$ 18	63 $\pm$ 32	0
Grouping ^a	a	b	b	c	a	a	d
Available N (0-15 cm)							
Mean $\pm$ S.D. (ug/g)	7.2 $\pm$ 3.9	4.6 $\pm$ 2.1	4.4 $\pm$ 2.4	6.4 $\pm$ 7.5	9.9 $\pm$ 6.2	2.6 $\pm$ 1.3	4.9 $\pm$ 3.7
Grouping ^a	ab	bc	bc	b	a	c	bc
Total N (0-15 cm)							
Mean $\pm$ S.D. (ug/g)	370 $\pm$ 116	403 $\pm$ 88	327 $\pm$ 43	317 $\pm$ 56	440 $\pm$ 85	294 $\pm$ 76	282 $\pm$ 78
Grouping ^a	bc	ab	cd	cd	a	d	d

S.D. = Standard Deviation

^a = Results of Duncan's multiple range test. Means with the same letter are not significantly different (P = 0.05).

seeded legumes and controls. Alfalfa is well adapted to a wide range of conditions, is relatively drought tolerant due to a deep root system and is moderately tolerant to alkaline soils. As a result, this adaptable legume was reasonably easy to establish. Biennial sweetclover was the easiest legume to establish and was very productive during the first year, but has to be reseeded every two years to maintain a continuous stand and did not always yield two cuts₂ per season. Sweetclover (313 g/m^2) and birdsfoot trefoil (286 g/m^2) yields were not significantly different, but were significantly more productive than all remaining legumes and controls except cicer milkvetch (234 g/m^2). Sweetclover is well adapted to a variety of growth conditions, has good drought tolerance and moderate tolerance to alkalinity. Birdsfoot trefoil has high tolerance to alkalinity, is fairly drought resistant and moderately tolerant of poor fertility. The birdsfoot trefoil was not as easy to establish as the alfalfa or sweetclover and provided patchy growth on some plots. Cicer milkvetch was more difficult to establish and contained numerous volunteer (weed) species. It has some tolerance to drought₂ and alkalinity, but is poorly competitive. Red clover (171 g/m^2) was very difficult to establish, so yields were not significantly different from the unseeded control (123 g/m^2). Red clover is adapted to a wide range of soil conditions, but has poor drought tolerance. The grass control (46 g/m^2) yielded significantly less plant biomass than all legumes and the unseeded control, but had no volunteer (weed) growth. Creeping red fescue is known for its tolerance to drought and poor fertility.

The requirement for available nitrogen by forage crops grown on normal agricultural soil has been described as deficient from 0-10 $\mu\text{g/g}$, marginal from 10-25 $\mu\text{g/g}$ and adequate from 25-38 + (Carson, 1986). In comparison, available nitrogen from the ash surface appears to be deficient in all legume treatments and controls. Available nitrogen (0-15 cm) was significantly higher under sweetclover than under all other legumes and controls, except alfalfa. Total nitrogen (0-15 cm) was also significantly higher under sweetclover than under all remaining legumes and controls, except birdsfoot trefoil. Total nitrogen was not significantly different under alfalfa and birdsfoot trefoil, but was significantly lower under cicer milkvetch, red clover and both controls. Cicer milkvetch and red clover did not have significantly different total nitrogen levels in the ash than both controls.

Conclusions

1. Sweetclover, alfalfa and creeping red fescue had better seeded species plant cover than the remaining seeded legumes. All three were relatively easy to establish. Once established, the alfalfa and creeping red fescue had very few weeds. The less easily established legumes, including birdsfoot trefoil, cicer milkvetch and red clover had higher occurrences of volunteer (weed) species.
2. Alfalfa produced more plant biomass than the other legume species and controls. Sweetclover was a vigorous, productive species, but has to be reseeded every two years (biennial) to

maintain a continuous stand. Birdsfoot trefoil produced well, but was a little more difficult to establish. Cicer milkvetch and red clover were both difficult to establish and had low yields.

3. Levels of available plant nitrogen in the ash were deficient across all treatments, however, sweetclover had more available nitrogen than all other seeded legumes. Total nitrogen was also highest under the sweetclover, while alfalfa and birdsfoot trefoil were higher than cicer milkvetch, red clover and both controls. Sweetclover appears to be fixing more nitrogen and improving soil fertility better than the other seeded legumes.

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ASSESSMENT OF VARIABLE SUBSOIL REPLACEMENT DEPTHS FOR
RECLAMATION OF SOILS AFTER SURFACE MINING (BRSRP)

L. A. Leskiw, C. Shaw-Nason and E. Reinl-Dwyer

Pedology Consultants
Edmonton, Alberta

ABSTRACT

The Battle River Soil Reconstruction Project (BRSRP) was established in 1979 to determine the most effective methods of reclaiming lands disturbed by surface mining of coal in the Battle River Coal Fields. The project is located 150 km southeast of Edmonton in a region dominated by Dark Brown Chernozemic and Solonetzic soils used for agriculture. Subsurface till materials are moderately saline and sodic but deeper mine spoils consist of unconsolidated bedrock that is weakly saline but highly sodic.

Results from the Subsoil Depth Experiment (one of the four experiments established) are addressed in this paper. The objective of the Subsoil Depth Experiment is to determine the optimum thickness of replacement subsoil over sodic minespoil. The thickness of subsoil replaced under 15 cm of topsoil ranged from 0 cm (Treatment 1) to 335 cm (Treatment 6).

Results from the Subsoil Depth Experiment indicate that forage, but not cereal, yields increase with increasing subsoil thickness. Data are presented that indicate these responses are primarily related to soil moisture regime rather than to soil chemistry. Further, data are presented to suggest that the different crops, cereals versus forage, have different and very important effects on soil chemistry and this is related to their influence on soil water status.

The combination of yield, soil moisture and soil salinity monitoring over a period of years provides extremely important insights into soil forming processes. This understanding is essential to establishing the sustainability of soil quality after mining and has very important implications to agricultural use of undisturbed lands.

INTRODUCTION

The Battle River Soil Reconstruction Project (BRSRP), featuring four experiments, was established in 1979. Objectives were to determine the most effective methods of reclaiming lands disturbed by surface mining of coal in the Battle River Coal Fields. This paper focuses on the Subsoil Depth Experiment which was designed to determine the optimum depth of replacement subsoil over sodic mine spoil required to sustain agricultural production. Results of four years of data collection are presented and discussed. The findings and opinions expressed in this paper are those of the authors, and not of the Alberta Ministry of Environment or any of its representatives.

SITE DESCRIPTION

The BRSRP is located about 20 km north of Halkirk on lands transferred from Manalta Coal Ltd. to the County of Paintearth. The dominant soils of the area before mining ranged from Dark Brown Solonetz to Orthic Dark Brown Chernozems developed on till deposits overlying the Horseshoe Canyon Formation which consists mainly of non-marine Cretaceous clayey sandstone, bentonitic mudstone and carbonaceous shale. Climate is continental with a frost-free period of approximately 100 days and an average annual precipitation of approximately 400 mm, 60% of which falls as rain during May through August.

Production of cereal crops and livestock are the major agricultural industries in the region.

METHODS

Experimental Design

Plots were established in 1980 using a randomized complete block design (Figure 1). Six treatments were established where the thickness of subsoil replaced over spoil increases from Treatment 1 to Treatment 6 (no subsoil, 25, 65, 135, 165, and 335 cm, respectively). A 15 cm layer of topsoil was replaced on the surface of all treatments. Topsoil and subsoil materials were obtained locally from an area of Orthic Dark Brown Chernozemic and Dark Brown Solod soils. Plots were constructed using mine machinery (dozers and scrapers) simulating the "take and put" system of mine reclamation (Parker, 1981). Crop type (forage, cereal) was crossed with the 6 treatments to produce 12 plots within each block which constitutes one of three experimental replicates (Figure 1).

Plot Monitoring

Each year soil and crop husbandry was practiced in a manner similar to that employed by local farmers. Soil parameters, crop yields and rainfall were monitored during each growing season.

In 1980 grab samples of construction materials were taken and analyzed to establish baseline conditions (Table 1). In subsequent years soil sampling was conducted in autumn. Two

Figure 1: Plot Layout for the Subsoil Depth Experiment

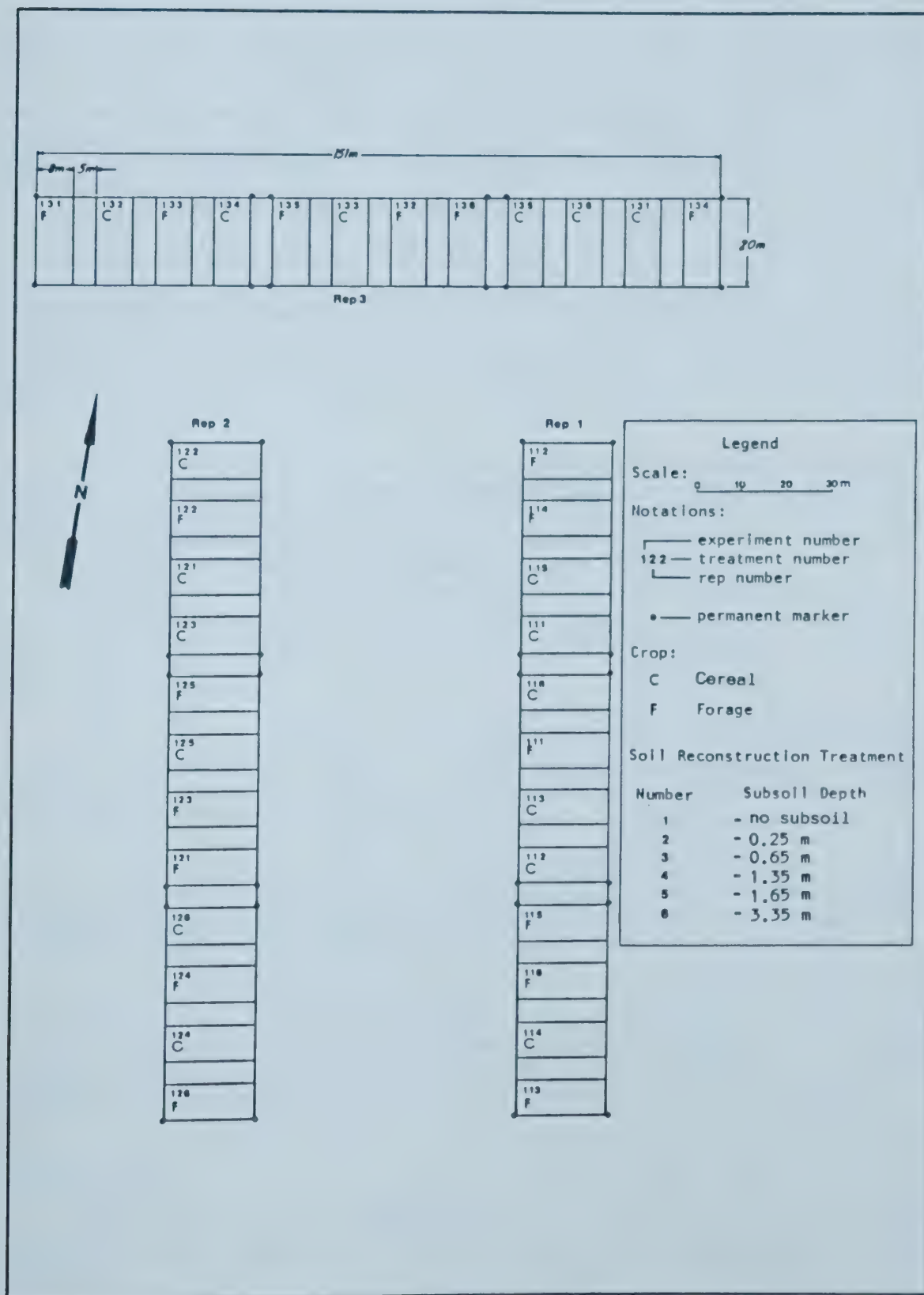


Table 1: Chemical Analyses of Materials Used in Plot Construction (Baseline Conditions).

Material ¹	EC (mS/cm) ²		Na (meq/L)		SAR		Reclamation Suitability Rating ³
	X	s.d.	X	s.d.	X	s.d.	
Topsoil	3.6	0.5	14.2	3.6	3.5	0.8	F (EC)
Subsoil	5.8	0.7	37.4	8.6	8.4	1.6	F-P(EC:SAR)
Spoil	2.9	1.0	27.2	9.0	23.9	2.7	U (SAR)

¹ Topsoil: Loam to clay loam textured A horizon removed from native soils before mining.

Subsoil: B and C horizons plus underlying material that has chemical and physical properties suitable for sustaining vegetative growth.

Spoil: Sodic bedrock materials of the Horseshoe Canyon Formation.

² EC: electrical conductivity
Na: sodium
SAR: sodium adsorption ratio

³ Proposed Alberta Soil Quality Criteria (A.S.A.C., 1981):

Ratings

F - fair
P - poor
U - unsuitable

Constraints

EC - high electrical conductivity (salinity)
SAR - high sodium adsorption ratio (sodicity)

samples within each plot were taken at 15 cm depth intervals to at least 50 cm into the underlying spoil. Chemical analyses which have been conducted by Norwest Labs using standard analytical procedures (McKeague, 1978) include pH, saturation percentage, SAR (sodium adsorption ratio), EC (electrical conductivity), and soluble Ca^{++} , Mg^{++} , Na^{+} , K^{+} , SO_4^{--} and Cl^{-} in the saturated paste extract. Neutron probe access tubes were installed in all plots in 1982 to facilitate measurement of soil moisture and bulk density. Soil moisture measurements have been taken on a monthly basis (May to September) at 15-30 cm intervals using a Campbell Scientific Subsoil Moisture Gauge (Model #503). Soil bulk density measurements were taken using a Campbell Scientific soil moisture/density probe (Model #501), in fall 1983 and in spring 1985, at the same depth intervals where soil moisture readings were taken.

Each April, soil samples were taken to determine fertilizer application rates for both cereal and forage crops. Cereal crops were seeded in May and harvested in mid-August of every year. Forage crops were established with a companion wheat crop in 1982. Forage crops were harvested in late July of every year: a second harvest was made only in September 1983. For further details regarding crop husbandry practices see Pedology Consultants (1983, 1984, 1985, 1986).

Forage and cereal yields are expressed on a dry weight basis (T/ha) calculated from entire plot fresh weights measured in the field and subsamples dried to a constant weight (forage) for 24 hours (cereal), at 60°C.

In 1983 the Alberta Research Council installed a rain gauge in the BRSRP compound to continually monitor precipitation (mm) from early May to late October.

Statistical Analyses

Statistical analyses were performed on yield data (forage and cereal separately) and on soil chemical data. The effects of factors in soil chemical properties were determined at four profile locations:

1. Topsoil (ts) above topsoil/subsoil interface
2. Upper subsoil (ss1) below topsoil/subsoil interface
3. Lower subsoil (ss2) above subsoil/spoil interface
4. Lower spoil (sp)

as well as for differences between the two subsoil layers ($\text{Diff } 1 = \text{ss2} - \text{ss1}$) and between the spoil and lower subsoil layer ($\text{Diff } 2 = \text{sp} - \text{ss2}$). The purpose of the latter procedure was to identify differential salt movement across treatments while avoiding the problem of heterogeneity of variance and co-variance across depths.

Within Years

The Subsoil Depth Experiment was analyzed as a randomized complete block design. Conceptually, treatment and crop were

fixed factors, replicate was treated as a random factor. The treatment main effect was decomposed into linear, quadratic and deviation planned comparison. For the planned comparison, homogeneity of variance was tested with Bartlett's test and Hartley's test at $p \leq 0.05$ (Winer, 1971). Tukey's HSD test at $p = 0.05$ was used for post-hoc tests. Statistical analyses (ANOVA's, homogeneity testing) were conducted using BMDP statistical packages on the AMDAHL mainframe at the University of Alberta. Means testing was conducted on the mainframe utilizing a custom program.

Across Years

Trends in soil chemistry since 1982 were analyzed using a split-plot design with years being within plot. Unless "year" interacted with any of the other factors, the trend across years was tested as the main effect and was decomposed into planned linear and deviation comparisons.

If "year" interacted significantly with Treatment and/or Crop, a planned comparison was performed at each factor level ($p=0.05$) (Myers, 1979). Tukey's HSD test at $p = 0.05$ was used for post-hoc tests.

RESULTS

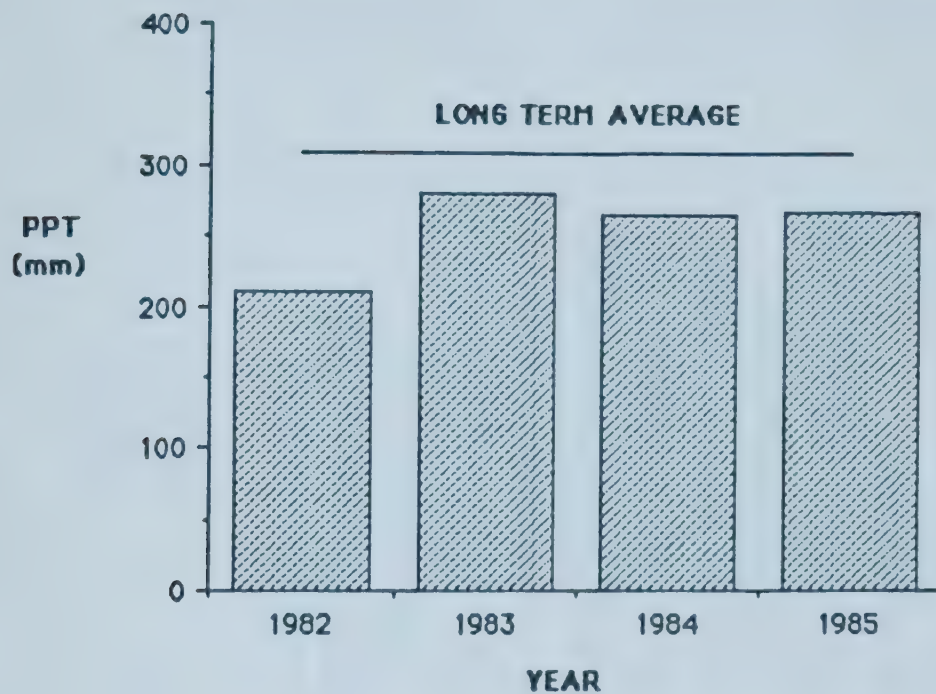
Rainfall monitoring results are summarized in Figure 2. Cereal and forage yield data for all years by treatment are shown in Figure 3 and long term average yields for both crops are shown in Figure 4. Examples of soil moisture (volumetric) distribution with depth under the two crops are shown in Figures 5-7.

Annual comparisons of soil chemical data are presented in Figures 8-10. Important crop effects on soil chemical properties are illustrated in Figures 11, 12 and 15. Treatment effects on soil chemical properties are presented in Figure 16.

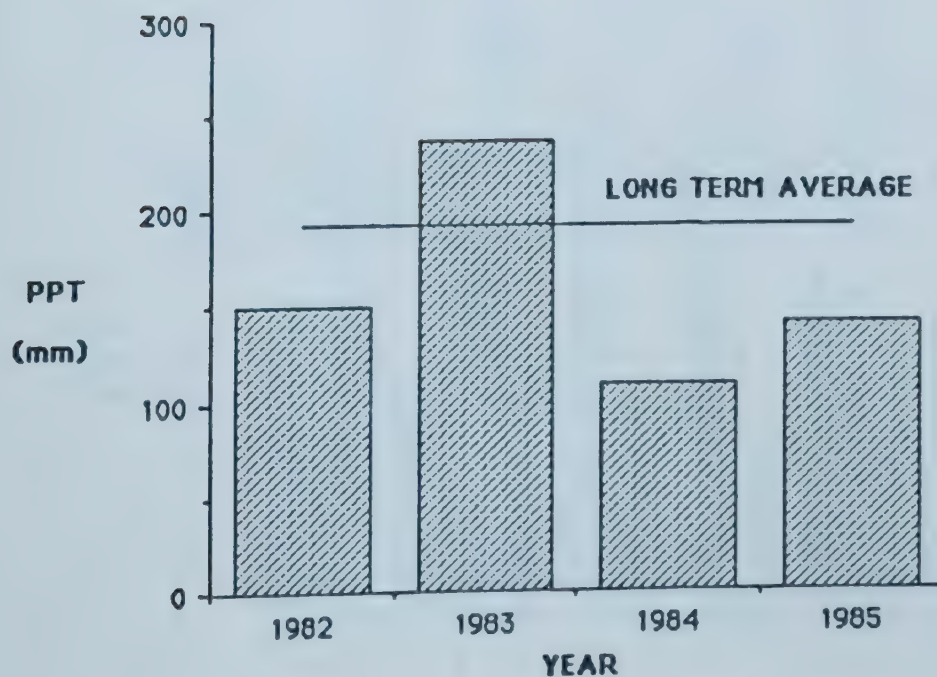
To summarize the large volume of soil moisture data collected, soil moisture classes were developed and their monthly frequency of occurrence tabulated (Figures 13 and 14). The data represent five monthly readings at several depths in each of three field seasons (1983-1985, total of 15 months) and two treatments (3 and 6) crossed with two crops (cereal, forage). The three classes at 0-5%, 6-10% and 11-20% above wilting point permit segregation of the less (0-5%) and readily (11-20%) available water. The percentage frequency distributions represent (for each depth) the number of months out of 15 which fell into each class. Results from the trend analyses of saturation % are shown in Figure 17 and associated regression analyses are found in Table 2.

In order to facilitate a comparison of treatment and crop effects on salinity in the rooting zone over the years, a mass balance approach was used. This approach eliminates some of the problems encountered when comparing profiles of such diverse and variable composition (e.g. Treatment 1-6). For each depth interval sampled (at the sample and replicate level) total salts (T/ha) were calculated as follows:

Figure 2: Total Precipitation at the BRSRP Compound (1982-1985)



2a. Total precipitation (mm) from May 1 to Oct. 31.



2b. Total precipitation (mm) from May 1 to July 31.

Figure 3: Mean Yields (T/ha) of Forage and Cereal Crops from 1982 to 1985.

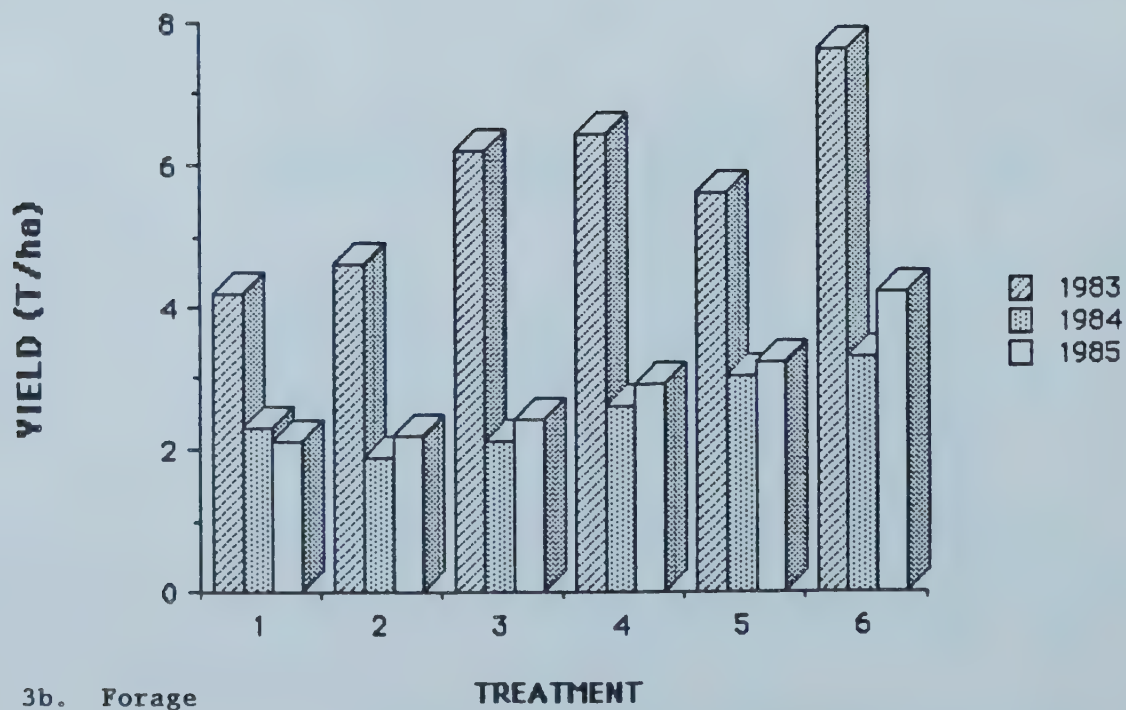
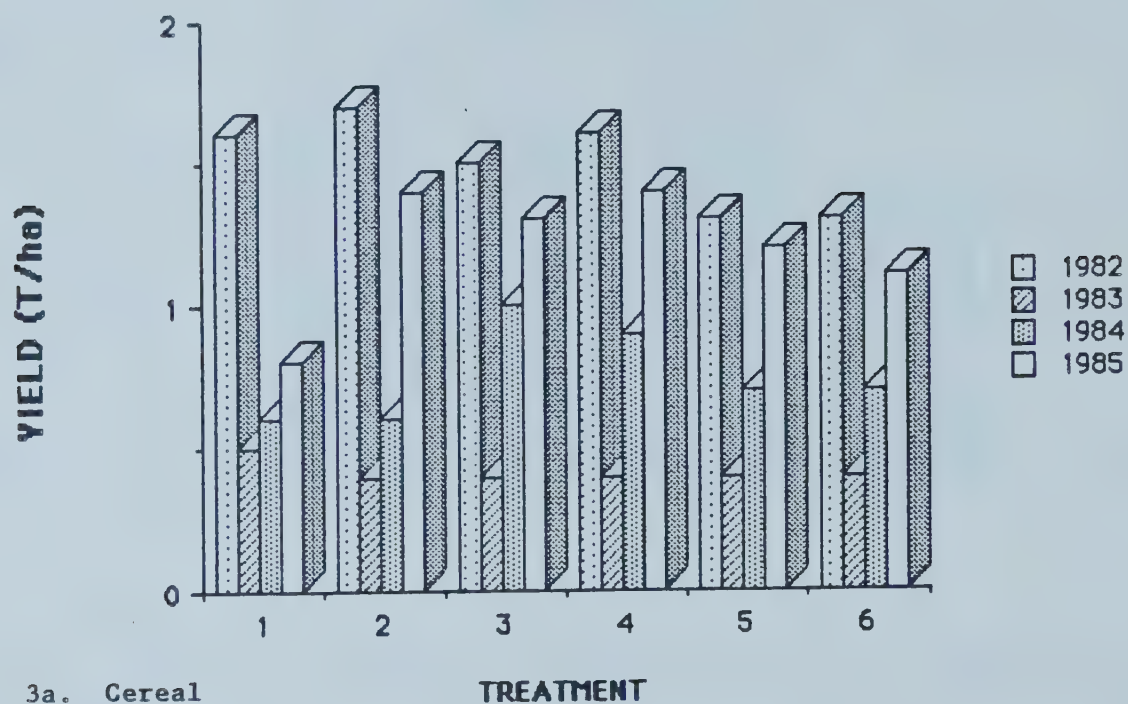


Figure 4: Long-term Yields (T/ha, 4-year average) of Cereal and Forage Crops for Six Treatments.

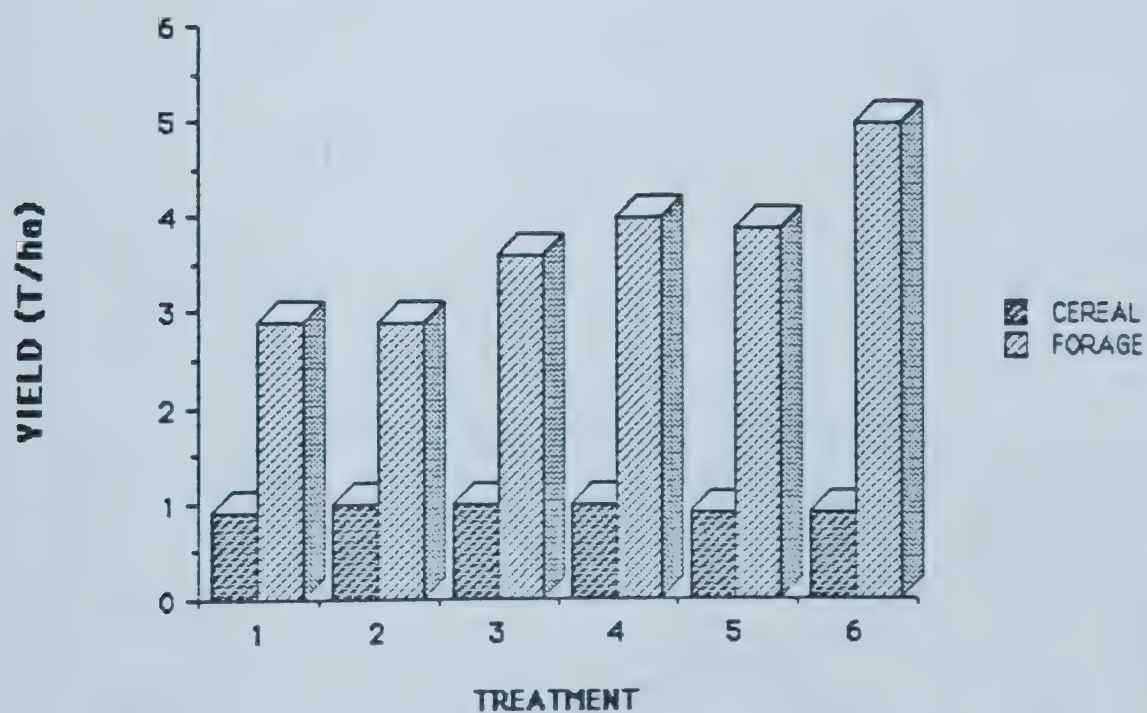


Figure 5: Distribution of Soil Moisture (% v/v) with Depth in May and July Under Cereal and Forage - Treatment 1 (1985).

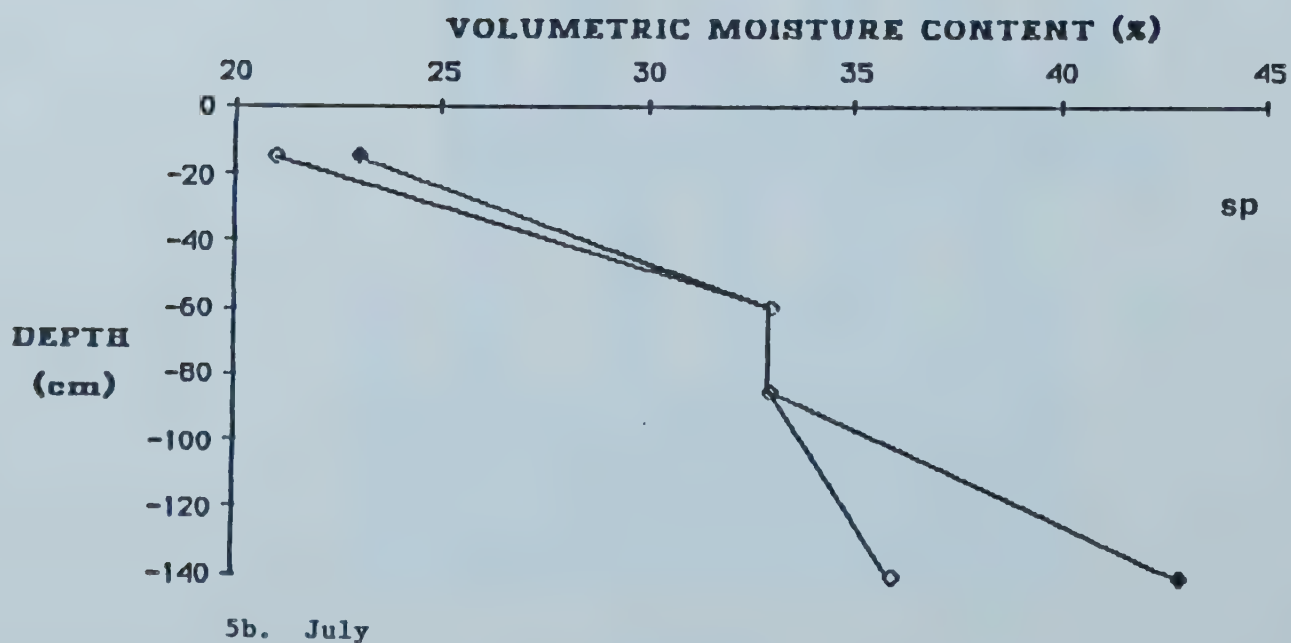
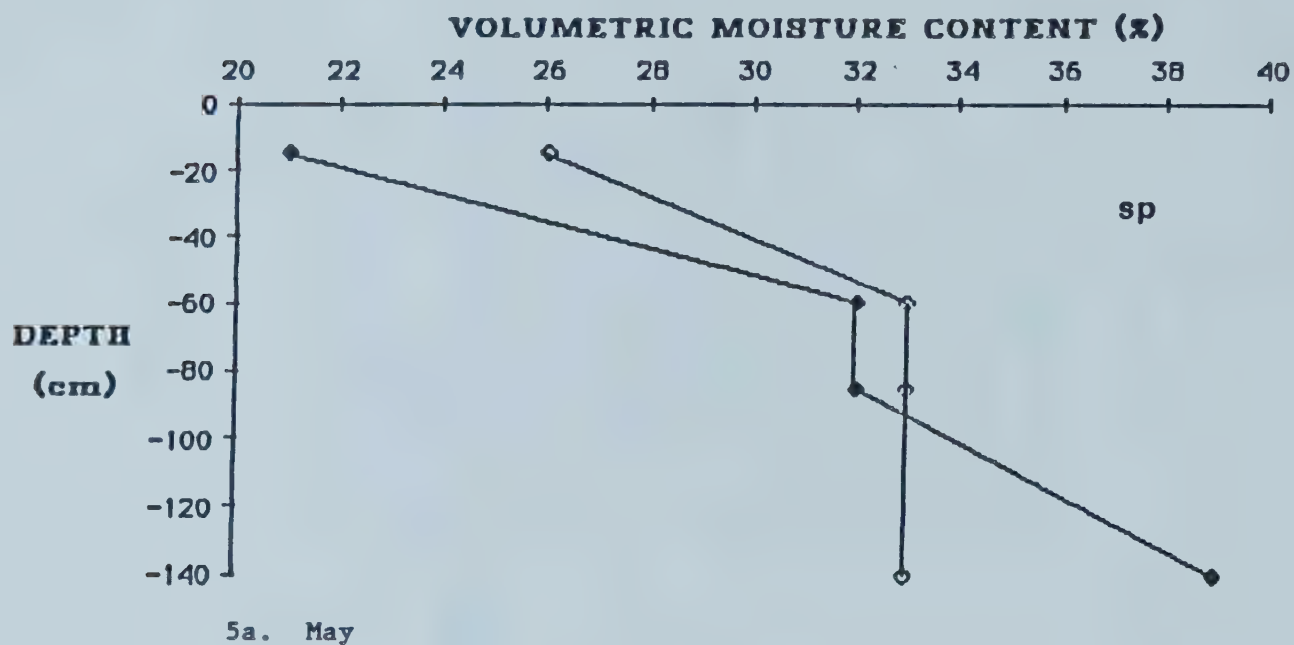


Figure 6: Distribution of Soil Moisture (% v/v) with Depth in May and July Under Cereal and Forage - Treatment 4 (1985).

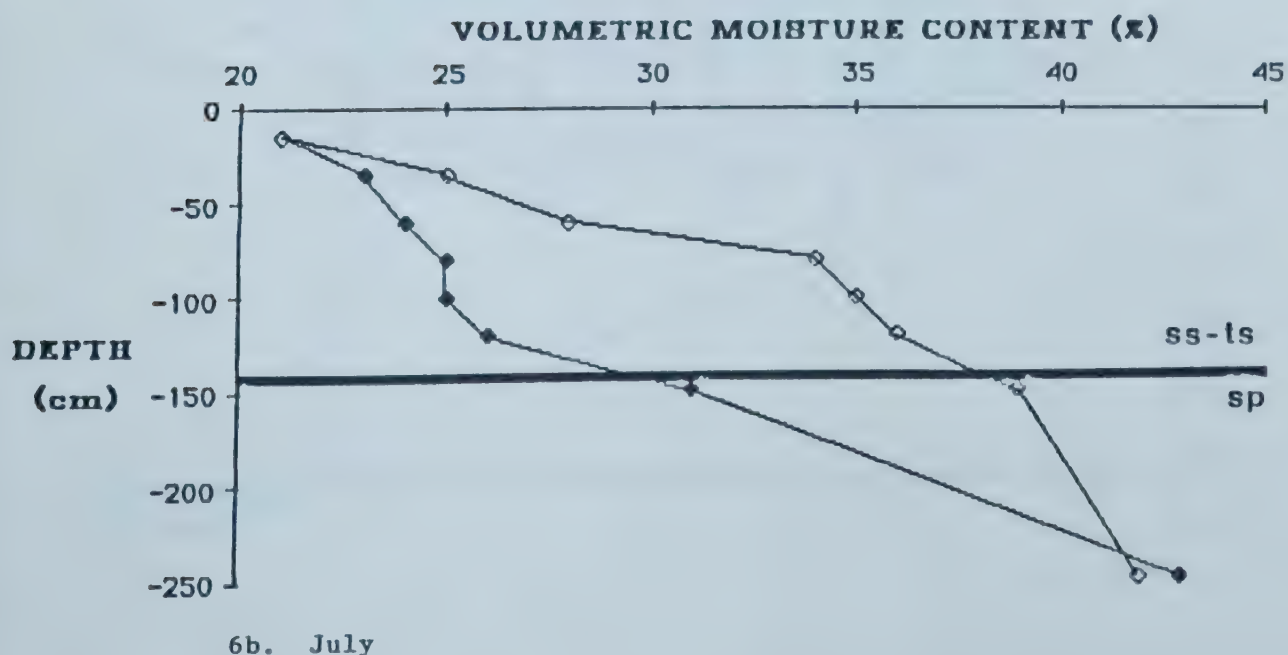
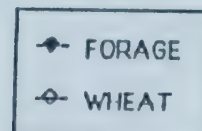
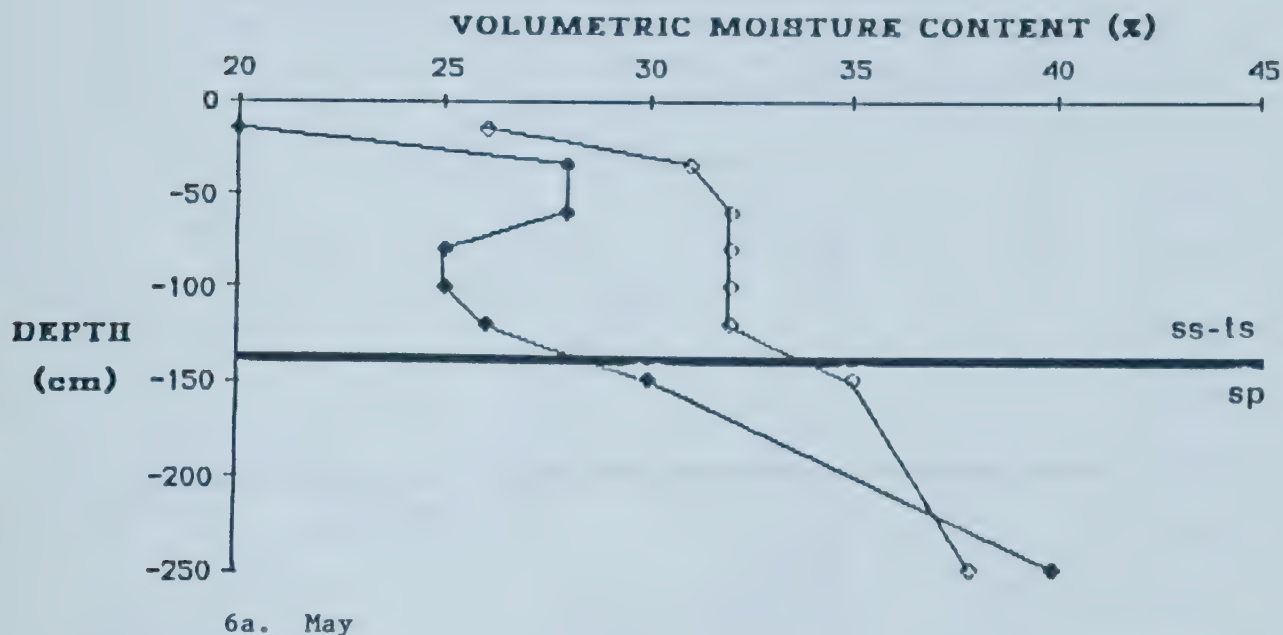
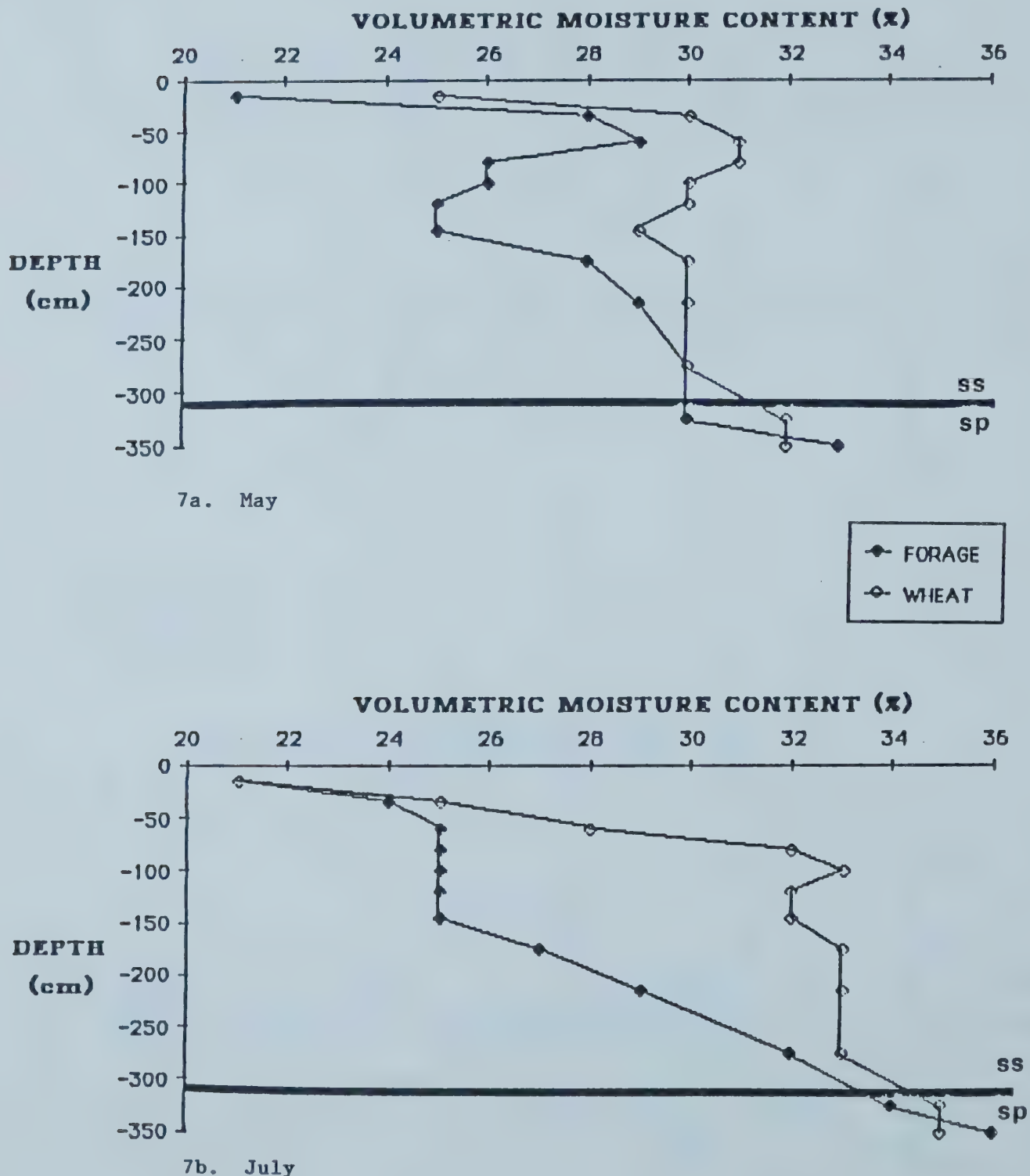


Figure 7: Distribution of Soil Moisture (% v/v) with Depth in May and July Under Cereal and Forage - Treatment 6 (1985).*



* Values within materials not accompanied by the same letter are significantly different ($p = 0.05$).

Figure 8: Mean EC (mS/cm) of Four Materials from 1982 to 1985. Values within materials not accompanied by the same letter are significantly different ($p = 0.05$).

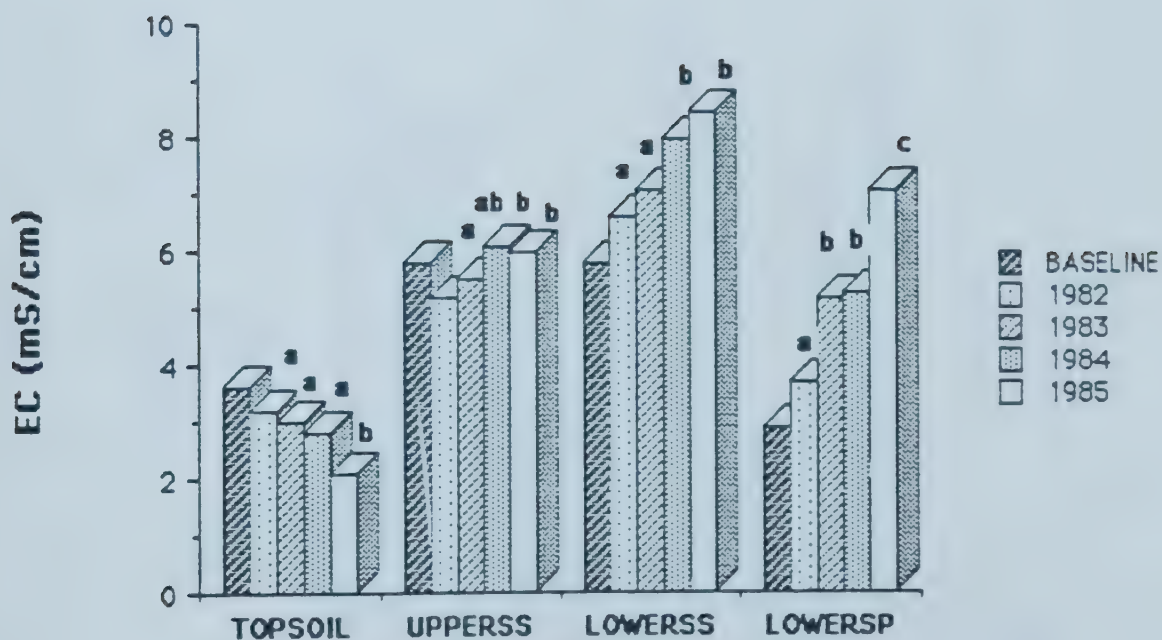


Figure 9: Mean SAR of Four Materials from 1982 to 1985.
 Values within materials not accompanied by the
 same letter are significantly different ($p=0.05$).



Figure 10: Mean Na Concentration (meq/L) of Four Materials From 1982 to 1985.

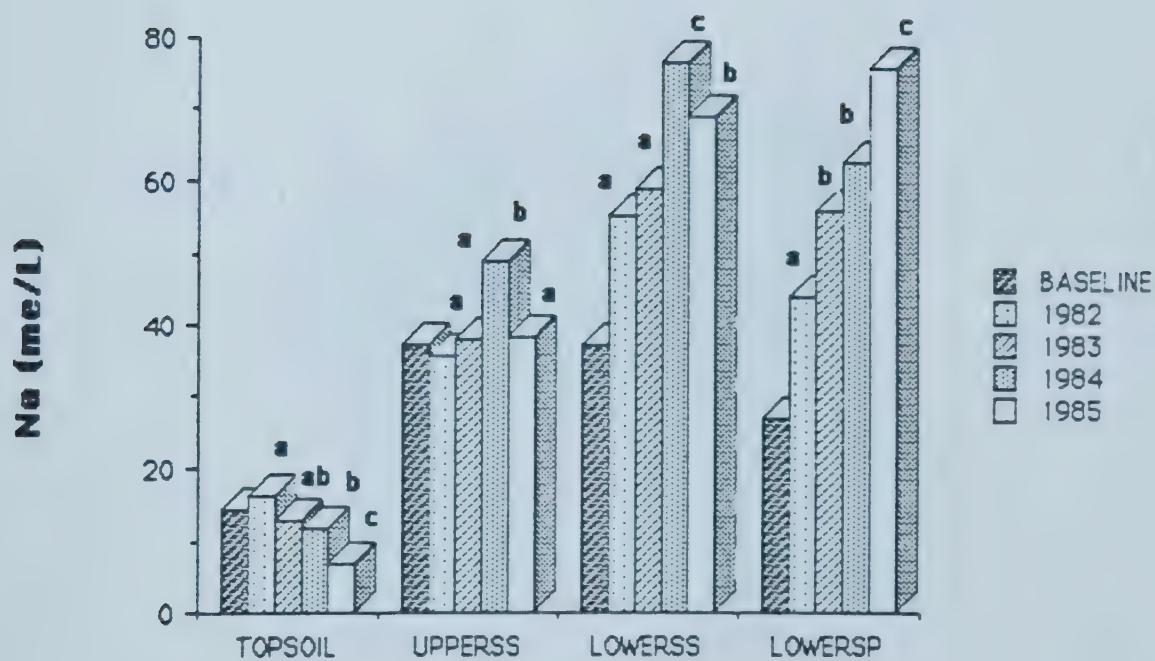


Figure 11: Annual Comparison of Topsoil Chemistry Under Cereal and Forage (1982-1985).
 Values within years not accompanied by the same letter are significantly different ($p = 0.05$).

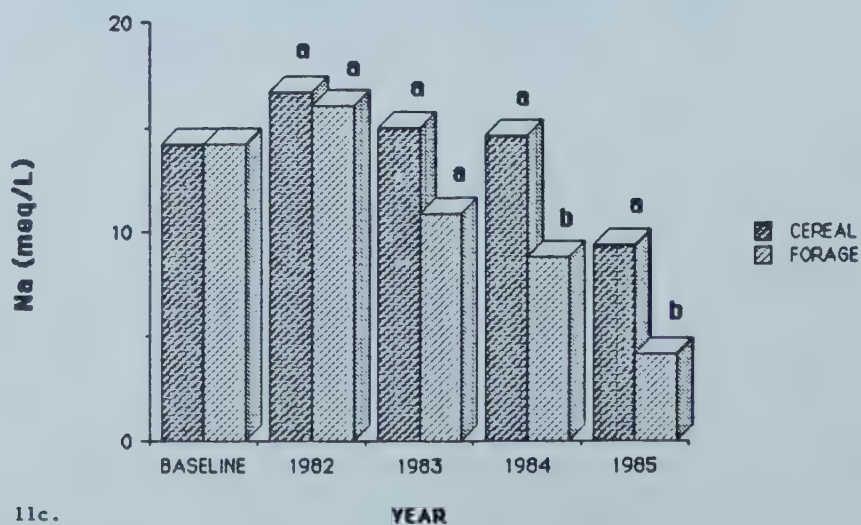
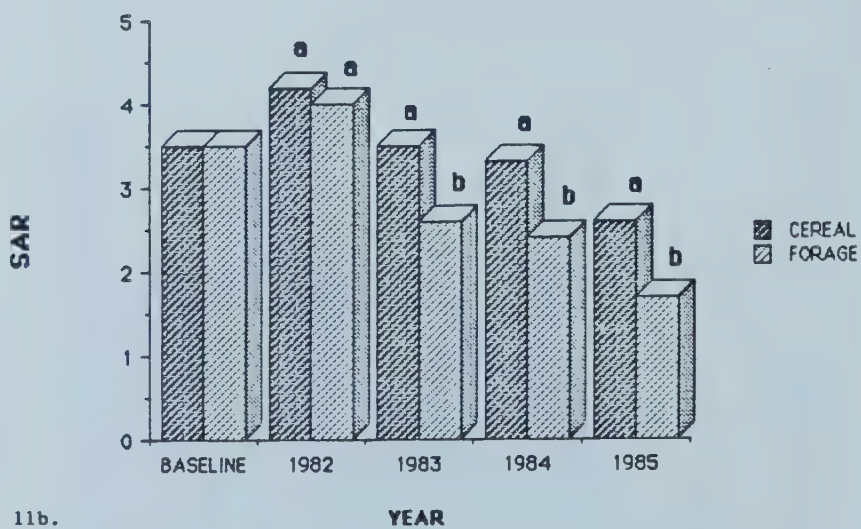
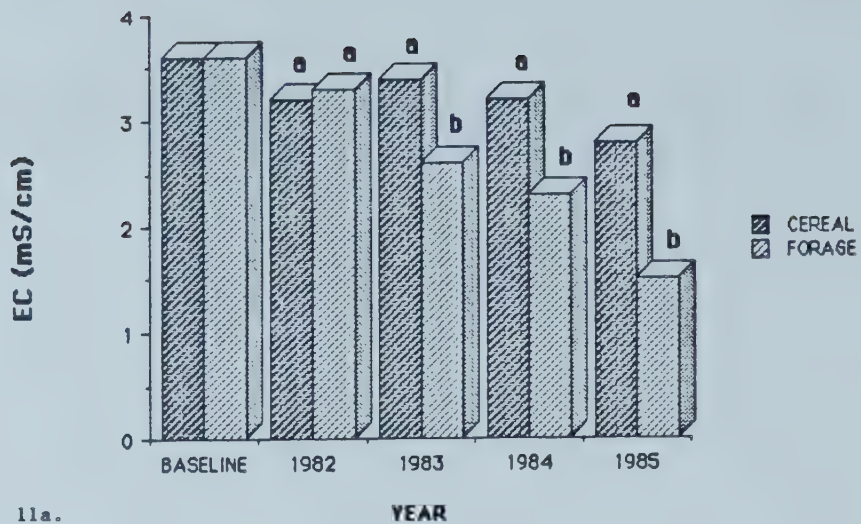


Figure 12: Mean EC (mS/cm) of the Upper and Lower Subsoil Under Cereal and Forage Crops (1985).

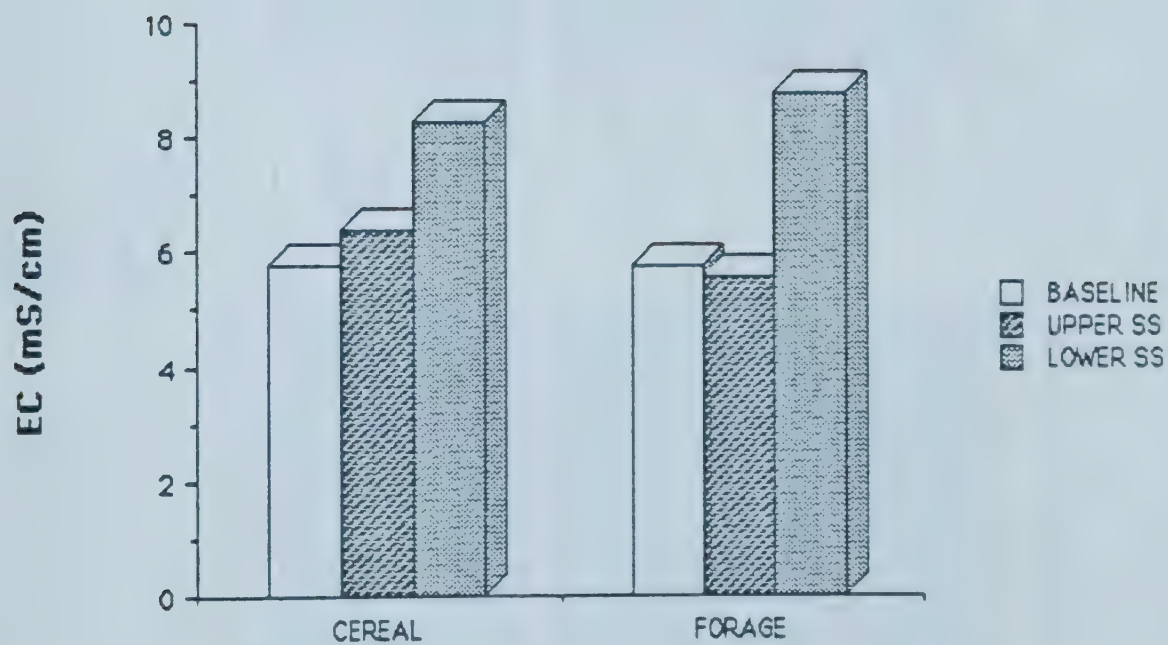


Figure 13: Frequency Distribution of Soil Moisture Under Cereal and Forage Crops - Treatment 3 (1983-1985).

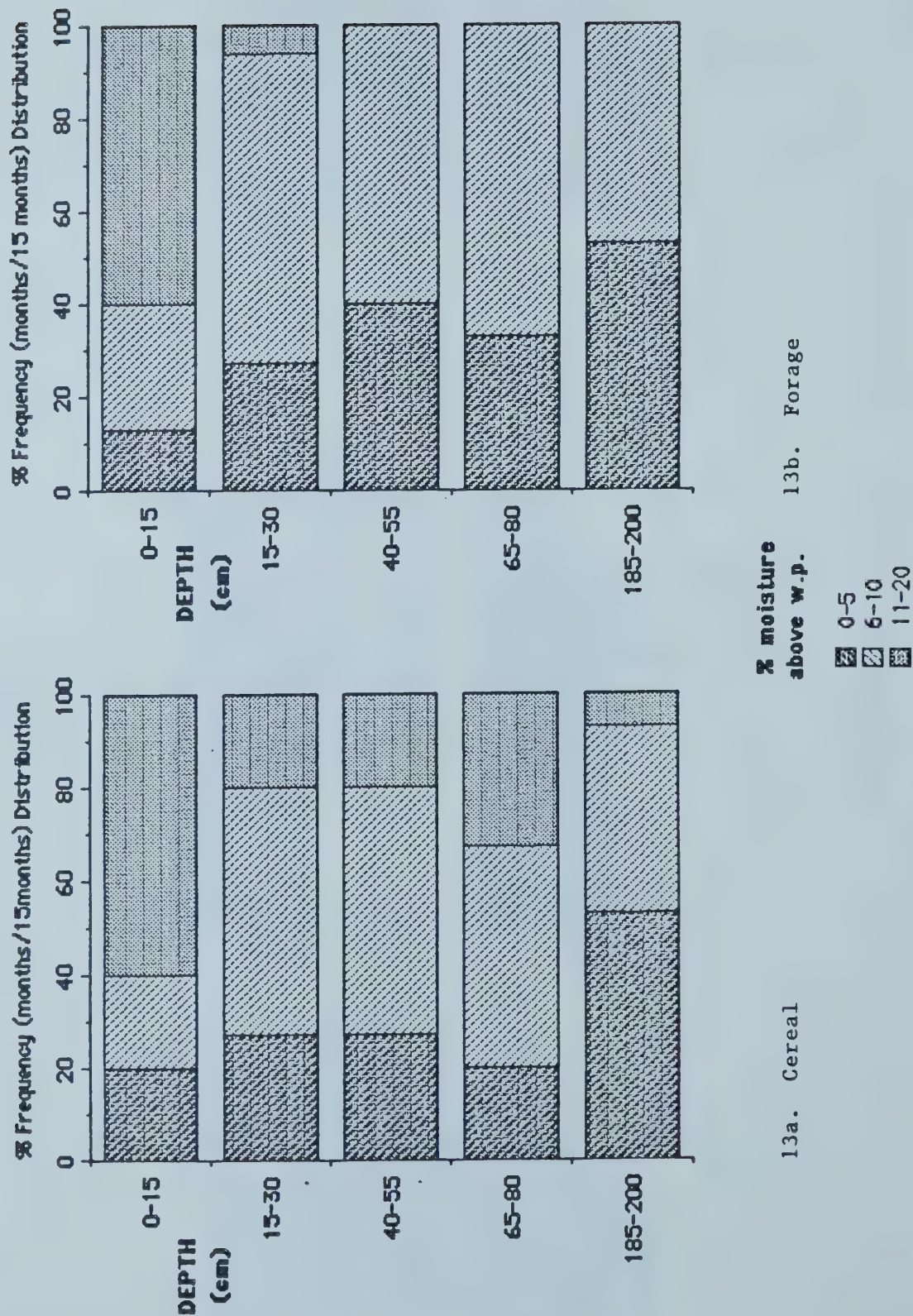


Figure 14: Frequency Distribution of Soil Moisture Under Cereal and Forage Crops - Treatment 6 (1983-1985).

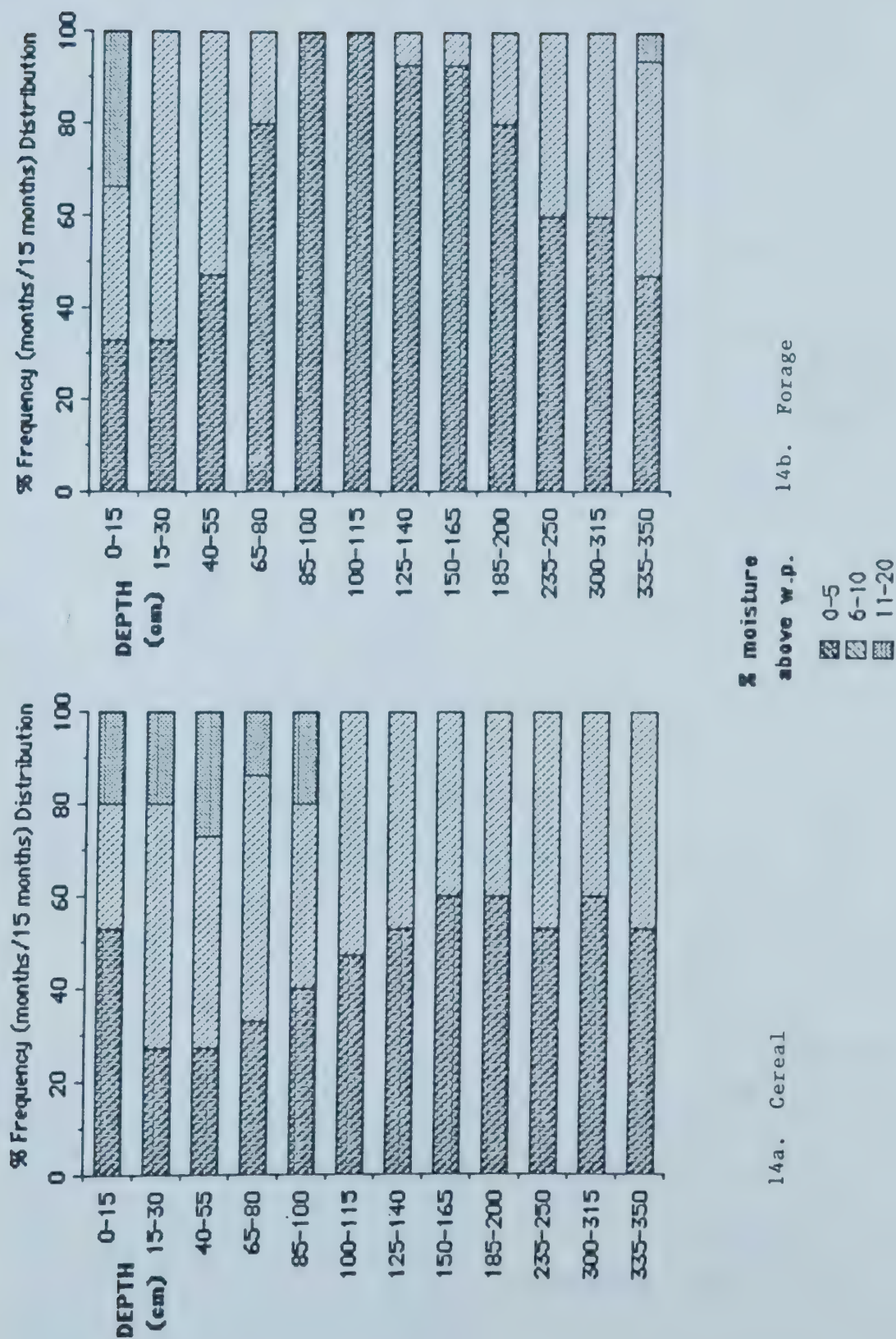


Figure 15: Distribution of Mean EC (mS/cm) with Depth Under Cereal and Forage Crops - Treatment 3 (1985).

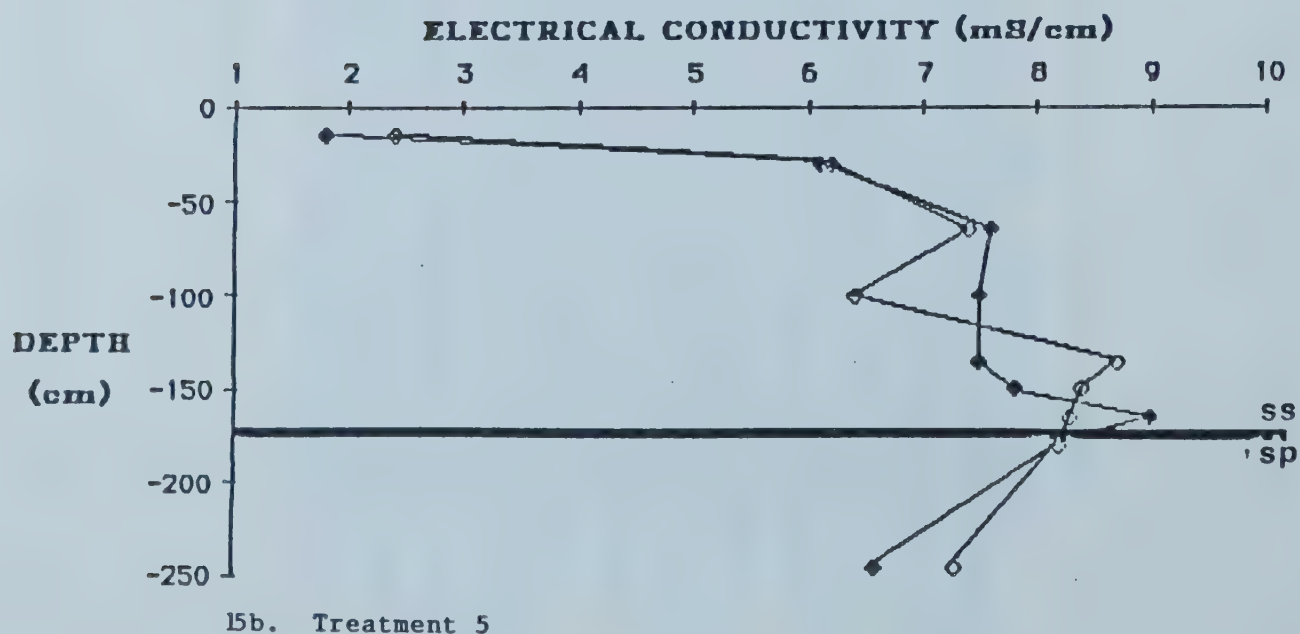
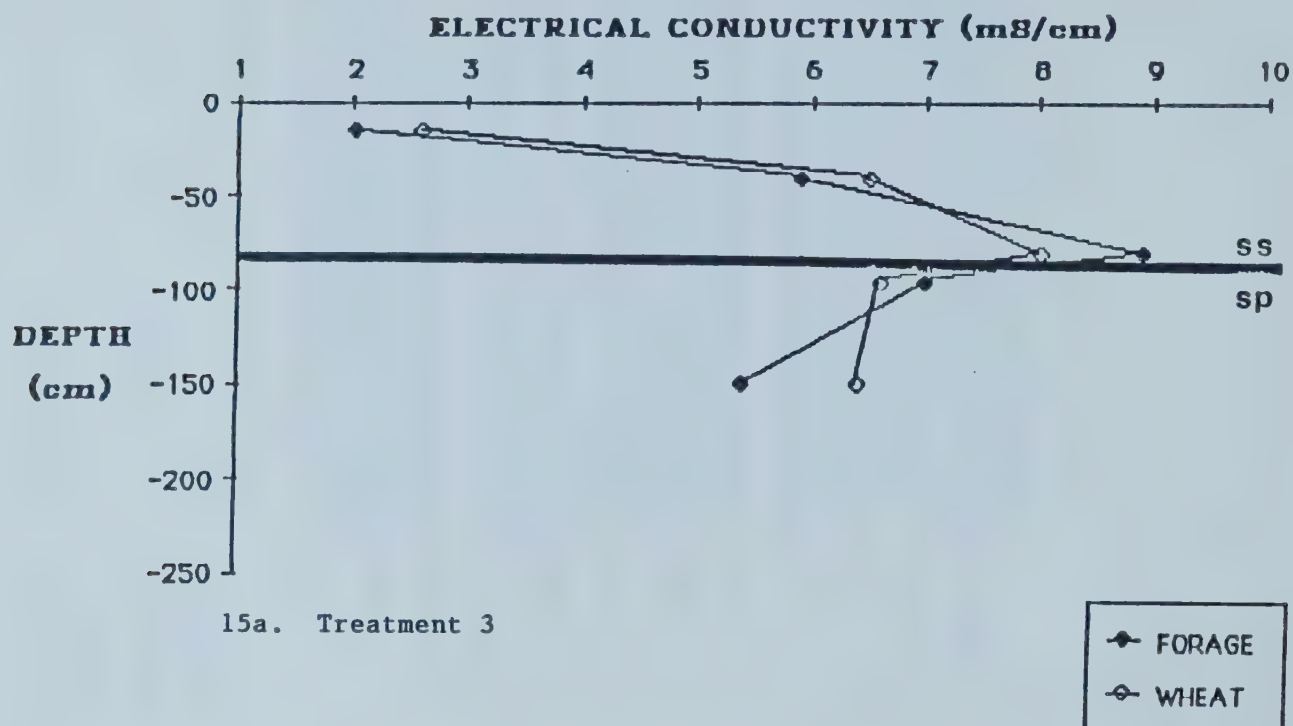


Figure 16: Mean EC (mS/cm) of the Lower Subsoil and Spoil from 1983 to 1985.

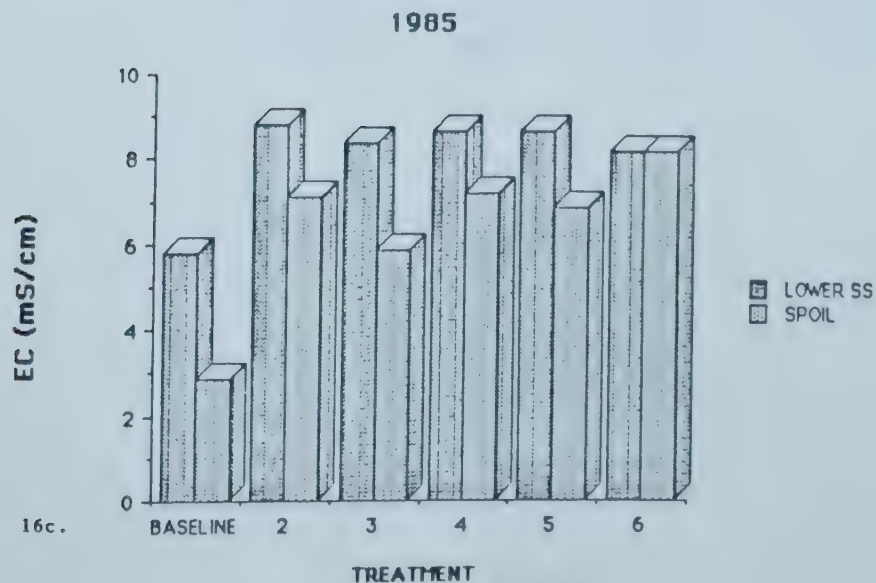
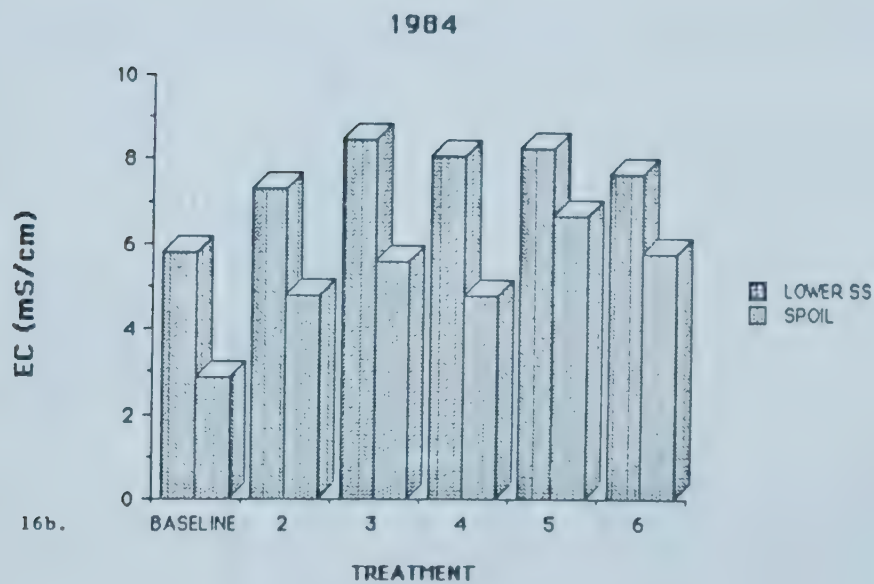
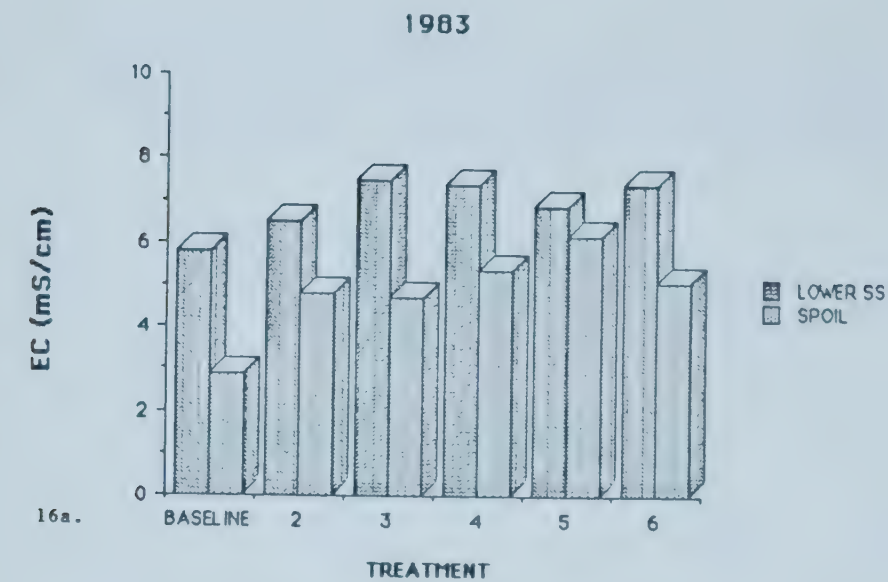


Figure 17: Mean Saturation % of Four Materials from 1982 to 1985. Values within materials not accompanied by the same letter are significantly different ($p = 0.05$).

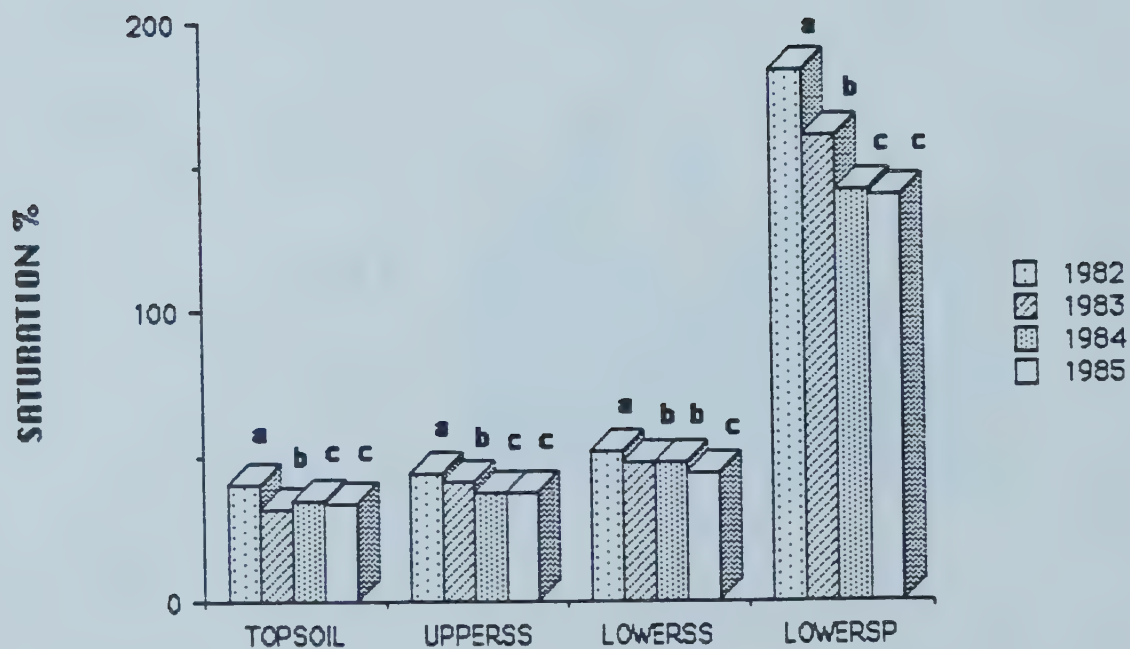


Table 2: Correlation (r^2)* of Saturation % with EC (mS/cm), Na Concentration (meq/L) and SAR for 4 Materials.

Material	EC (mS/cm)	Na (meq/L)	SAR
Topsoil	+ .19	+ .35	+ .57
Upper SS	- .96	- .46	- .35
Lower SS	- .81	- .34	- .40
Spoil	- .75	- .86	- .60

* based on regression of means shown to be significantly different in annual comparisons.

$$\text{EC (mS/cm)} \times 850^* (\mu\text{g/ml}) \times \text{Saturation \% (ml/100g soil)} \times \\ \text{Bulk Density (g/cm}^3\text{)} \times \frac{1 \text{ tonne}}{10^{12} \mu\text{g}} \times \frac{\text{cm}}{\text{depth interval}} \times \frac{10^4 \text{ cm}^2}{\text{m}^2} \times \frac{10^4 \text{ m}^2}{\text{ha}}$$

* Source: Stanley/SLN Consulting, 1978.

The appropriate number of depth intervals were summed to 140 cm. Means resulting from these calculated values are presented in Figure 18.

DISCUSSION

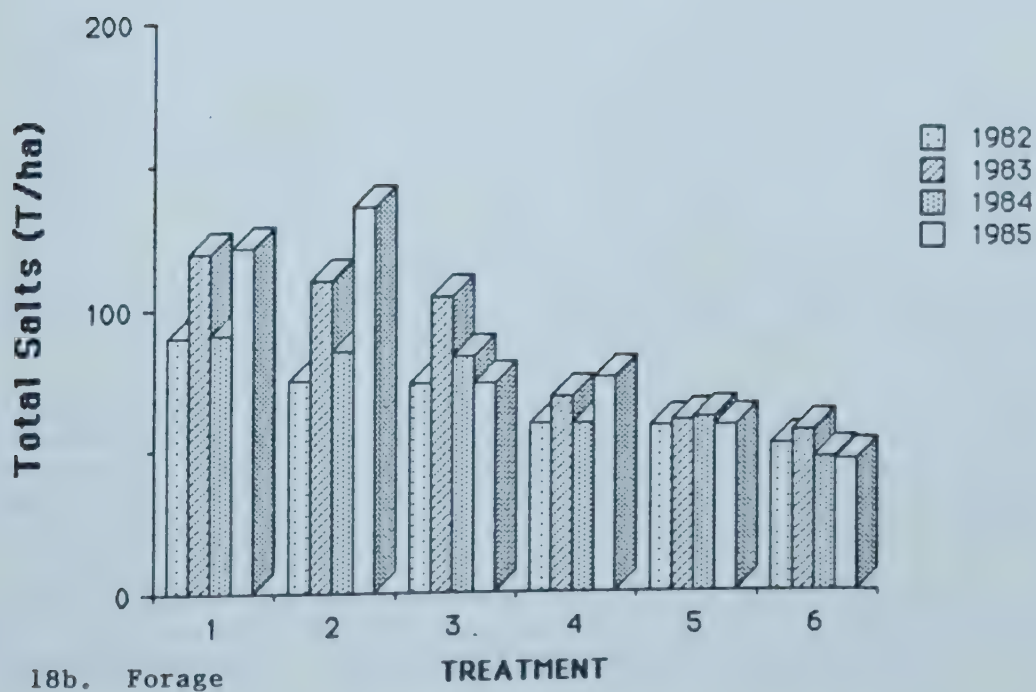
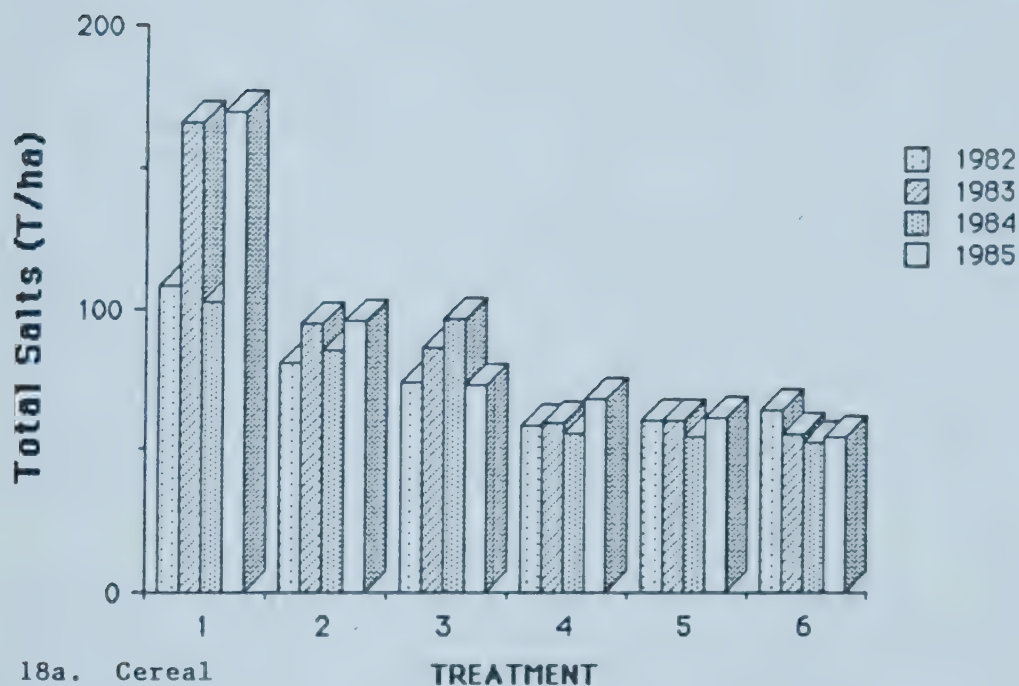
Crop Yields

Results to date suggest that crop yield on the reconstruction site is more dependent on soil moisture status than on soil chemical properties. The four years over which data have been collected have been drier than normal (Figure 2). Regressions of crop yield and total rainfall during the cropping season (May 1 - July 31), showed a high correlation ($r^2 = 0.98$) with first-cut forage yield but a low correlation ($r^2 = 0.28$) with cereal yields.

The high correlation of forage yields with rainfall reflects the ability of forage with its extensive rooting system (to greater depth than cereal) to access and therefore extract moisture stored deeper in the soil. Forage yields in every year increased linearly (statistically significant trend) with increased subsoil depth (Figure 3b). This trend is so consistent and strongly expressed it is reflected in long term yields (Figure 4). These yields are relatively independent of distribution of precipitation events which supports the interpretation that forages extract moisture stored in the deeper subsoil layers.

The low correlation of cereal yields to total growing season precipitation appears to reflect the inability of cereals to access soil moisture stored at depth. Since their rooting systems are shallow, yields are responsive to the dynamics of soil moisture status near the surface. Treatment effects on cereal crop yields were not strong nor consistent through the years (Figures 3a and 4) but variations in yield were closely linked to differences between the years in timing of major precipitation events. In 1982 and 1985 precipitation was evenly distributed throughout the growing season allowing good germination in the spring and providing limited moisture during the remainder of the growing season to the shallow rooting system. Consequently, yields were higher in these years than in 1983 and 1984. Although total precipitation during the 1983 growing season was high, the distribution was poor. In early May precipitation was high resulting in excellent germination. Subsequently, a long period with very little rainfall resulted in poor growth and some mortality, indeed the crops never recovered from this early drought. In 1984 the first major rainfall did not occur until

Figure 18: Total Salts (T/ha) in the Rooting Zone (140 cm) Under Forage and Cereal Crops (1982-1985).



mid-June, therefore germination was delayed, uneven, and poorer than in years where rainfall was good in May. As a result yields were lower than in 1982 or 1985 but better than in 1983.

The difference in ability of the two crops to withdraw moisture stored in the soil can be further supported by soil moisture/depth relationships beneath the two crops (Figures 5-7). Trends for soil moisture with depth under the two crops were similar in 1984 and 1985 (Pedology Consultants, 1985;1986). Moisture profiles from three treatments (1, 4 and 6) at the beginning and end of the 1985 growing season are shown in Figures 5-7. Where spoil impedes root development (Treatment 1 - Figure 5) trends for soil moisture are similar for both crops. Where subsoil is 135 cm thick (Treatment 4) the distribution of soil moisture beneath the two crops is different (Figure 6). This difference is most strongly expressed at the end of the growing season. Soil moisture sharply increases below 50 cm under cereal whereas soil moisture remains low to about 140 cm under forage and then sharply increases. These depths (50 and 140 cm) correspond to the depths of rooting observed in the field. Further, the area between the two curves (cereal and forage) likely represents the additional soil water utilized by the forage, but not cereal, crops. A similar phenomenon exists for Treatment 6 (Figure 7). In this case where subsoil thickness is about 330 cm the area between the curves in July is even greater than for Treatment 4.

Soil Chemistry

Results in Figures 8-10 illustrate general trends for soil chemistry by layer and year (no treatment or crop interactions). Values for EC (Figure 8) indicate that in general salinity has increased in the upper and lower subsoil and spoil while it has decreased in the topsoil. Statistical analyses of the difference between upper and lower subsoil, and spoil and lower subsoil, indicate that the rate of increase in salinity is greater in the lower spoil than lower subsoil and greater in the lower than upper subsoil. The significant decrease in EC values for the topsoil should be accepted with caution as a general trend since there is a significant interaction with crop (Figure 11a - discussed later). General trends for SAR (Figure 9) and Na concentration (Figure 10) are similar to those for EC for the topsoil (significant linear decrease) and lower subsoil and spoil (significant linear increase). Only the upper subsoil exhibits no significant linear trend for Na concentration or SAR. The dynamic nature of the subsoil zone (additions and removals of salts/Na from leaching/diffusion and convection) likely accounts for the lack of a consistent linear trend in the upper subsoil.

Although general trend data indicate that salinity and sodicity are on the increase for most materials at depth, and on the decline in the topsoil, significant results at the interaction levels suggest that the rate and nature of these trends vary depending on the treatment (subsoil thickness) and type of crop.

The strongest interaction effects on soil chemistry result from crop influences. Within year values for EC (1983-1985), SAR (1983-1985) and Na concentration (1984, 1985) in the topsoil are

significantly lower under forage than under cereal crops (Figure 11). The linear trend for decreasing EC values from 1982 to 1985 (Figure 11a) under forage is highly significant. Although similar trends under forage exist for SAR and Na concentration (Figure 11b,c) they were not shown to be statistically significant.

In 1985 the type of crop also influenced soil chemistry at depth. The differences in EC values between the upper and lower subsoils are significantly greater under forage than under cereal (Figure 12). This may be attributed to a greater decrease in the upper subsoil EC and greater increase in lower subsoil EC relative to baseline conditions, under forage than under cereal crops (Figure 12). Similarly, SAR values of the spoil were significantly higher under forage than under cereal crops (data not shown).

These data (forage - decreasing values in ts, upper ss; increasing values in lower ss, sp) suggest that forage crops tend to produce a leaching environment favouring removal of salts/Na in the upper profile, more so than cereal crops. This may be attributed to differences between the crops rooting systems and their influence on the soil moisture regime. The extensive and deep rooting system of the forage crops when compared to cereal crops maintains drier conditions to a greater depth, for a greater portion of the growing season (Figure 13, 14). The maintenance of dry conditions along with the well established rooting system of the forage crops likely produces a soil structure characterized by numerous voids, cracks and fissures. During the few major rainfall events (common in this region) leaching and removal of salts/Na from the upper to the lower profile is likely favoured under forage over cereal due to greater contact of water with topsoil and subsoil materials. A comparison of soil moisture frequency distribution with depth (Figures 13, 14) with distribution of EC with depth (Figures 15 a,b) further supports this interpretation. In Treatment 3 where rooting depth of the two crops is similar due to impediment to growth by the spoil, trends for EC with depth are similar (Figure 15a) and soil moisture distributions are somewhat similar with forage being slightly drier than cereal at depth (Figure 13). Where more subsoil is present soil conditions are considerably drier under forage than under cereal (Figure 14) and the EC values from 130 to 160 cm depth are lower under forage than under cereal (Figure 15b).

Statistically significant interactions at the treatment level were few and for the most part inconsistent. The only statistically significant and consistent trend was that EC values in the spoil increased at a faster rate than the lower subsoil (Figure 16). The linear trend of the difference between the lower subsoil and spoil was not significant in 1983 but was significant in 1984 and 1985. To discern if improvements in soil chemistry occur in, for example, the rooting zone as a result of increasing subsoil thickness, comparisons should be made at the same depth for the same material across all treatments. In future, this approach should be tested in addition to existing analyses.

Figure 17 illustrates significant differences in saturation %

between years for the four different layers analyzed. Concern arises when differences or trends in means for saturation % mirror those for chemical analyses since results upon which interpretation across years are based may be an artifact of year to year differences in saturation %. Regression analyses of significant means from chemical results with saturation % show that values for EC (upper subsoil, lower subsoil, possibly spoil) and Na concentration (spoil) may co-vary with saturation % (Table 2).

Some of the problems associated with differences in saturation % and comparing profiles of highly variable composition can be dealt with by taking a mass balance (total salt) approach to assessing soil salinity. Total salts (T/ha) in the rooting zone (140 cm) under cereal and forage crops were calculated for 1982-1985 (Figure 18). These data suggest that regardless of crop type salt fluctuations in the top 140 cm are very strong when the spoil is within 150 cm of the surface. In order to discern more clearly the thickness of subsoil necessary to avoid large fluctuations in salt movement mass balance calculations refined to small depth increments may be required. The variability of these data over the years (especially for treatments 1-3) confirms the necessity of long term monitoring to facilitate valid long term prediction of trends for soil quality.

CONCLUSION

Crop yields at the reconstruction sites are more dependent on soil moisture status than on soil chemical properties. This relationship has been observed during a drier than normal four years over which data have been collected. In every year forage, but not cereal, yields increased linearly with subsoil thickness to more than 3 meters reflecting the ability of the forage's extensive rooting system to draw on stored soil moisture. Variable cereal yields were linked to differences between years in the distribution of major rainfall events.

Annual comparisons of the chemistry of the layers above and below interfaces (topsoil, upper subsoil, lower subsoil, spoil) indicate that, in general, salinity and sodicity is increasing at depth (lower subsoil, spoil) and decreasing in the topsoil. It is surprising that there has been so much salt movement under relatively dry soil conditions (and no shallow water table). Significant results at the interaction levels suggest that the rate and nature of salt movement depends on the treatment (subsoil thickness) and type of crop (cereal versus forage). The strongest interaction effects resulted from crop influences. The data suggest that conditions under forages, but not cereals, are conducive to leaching and removal of salts/Na from the upper into the lower part of the profile. This is attributed to forage rooting systems maintaining drier conditions and producing more fissures, cracks and voids, in the subsoil than do cereal rooting systems. During the few intense rainfall events (common to the area) leaching and downward movement of salts is apparently favoured by relatively rapid percolation of water through the fractured topsoil and upper subsoil. Statistically significant interactions at the treatment level were few and inconsistent

through the years. In order to discern if upper profile soil chemistry improved as a result of increasing subsoil thickness additional comparisons should be made at the same depth for the same materials across all treatments, and longer term monitoring is recommended.

Regression analyses of saturation % with soil chemical properties (by interface layers) suggest that care must be taken in accepting annual trends for EC (subsoil, spoil) and Na concentration (spoil) since they could be artifacts of analytical differences from year to year. Some of the problems associated with differences in saturation % and comparing profiles of variable composition can be dealt with by taking a mass balance approach to assessing soil salinity. Preliminary total salt (T/ha) calculations indicate that large fluctuations in salt movement occur in the top 140 cm when the spoil is within 150 cm of the surface.

In the four years of monitoring crop yields and soil properties it is clear the evaluation of reclamation success or sustainability of agricultural production is not a straightforward exercise. Different crops lead to different conclusions; variations in rainfall are very important in affecting salt movement; evaluation of soil EC and SAR should be supplemented by salt balance calculations; and rainfall and moisture supplying ability of the soil play key roles in crop productivity as do management practices. Might the production of cereal crops on the prairies, versus native grasses, result in subsoil salinization even where water tables are deep? In the authors' opinion, more comprehensive long term studies should be undertaken to gain a better understanding of interactions of factors influencing soil development. Land reclamation research appears to be ahead of agricultural research in this regard.

ACKNOWLEDGEMENTS

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RESTORATION IN NORTHERN ENVIRONMENTS
USE OF SEA LYME GRASS

Francois Gauthier, F.E.
Environment directorate
Hydro-Quebec

ABSTRACT

Following Hydro-Quebec's decision not to proceed with a hydroelectrical project near the Hudson Bay, it was further decided to improve the bare site of the exploration camp and to restore it to its original state by planting green plants that harmonize with the local vegetation.

This called for a special technique, since the area is situated on the shoreline and has the following distinctive characteristics: a northern location, proximity to the sea, vulnerability to wind erosion and a particular soil texture and composition.

Therefore, when formulating a method for restoring the area to its natural state, we sought the most economic technique and took into consideration the characteristics of the terrain.

The first step was to determine the kind of plants that could be introduced at such a location. A review of the existing literature and an inventory of the local vegetation led us to the conclusion that sea lyme grass (*Elymus arenarius*) would be the best plant for restoring the terrain to its natural condition.

The technique selected for our work on the site was transplantation which we felt was the most suitable and effective method for a northern environment. Plants growing in a similar environment were dug up and replanted in the area to be restored, using the following three types of replanting: the replanting of clods, of individual plants and of clumps or tufts.

The transplantation was carried out in Summer 1983 and assessment of the results was made during the Summers of 1984 and 1985.

The operation seems to have been highly successful with more than 95% of the plants surviving transplantation. Examination of individual plants showed excellent development of the root systems and, in several cases, propagation by the rhizomes had begun.

This experience enables us to envisage the improvement of other disturbed areas in the north. For example, there are frequent problems with unstable sand near native villages. Although different plant species might be introduced, depending on the constituents of the environment, the principal replanting techniques could nevertheless be used.

INTRODUCTION

Because construction work inevitably causes soil disturbance, appropriate mitigation measures must be planned to restore the site after it closes.

Hydro-Quebec has developed a site-restoration technique for use in northern environments, which uses the fast-spreading plant known as sea lyme grass (*Elymus arenarius*) and the method of replanting.

This technique allows labour to be hired locally, and thus reduces the costs. Both the technique and its success rate have proved significant.

We are convinced that this technique could be adapted to other plants specific to Canada's northern regions.

THE PROBLEM

Hydro-Quebec has several active hydroelectric development projects in northern Quebec that involve the construction of power stations and of dikes modifying the normal course of rivers. These major projects inevitably disturb the initial soil structure and appropriate mitigation measures are therefore planned from the start of work: minimizing wood clearing, reducing disturbance to sensitive soil areas such as river banks and erodible zones, and conserving the existing organic matter. In order to speed up the reconstitution of the disturbed areas, the sites are restored and replanted after closure.

The environmental problem is compounded if the territory lies north of the 50th parallel. This distribution of the plants Hydro-Quebec generally uses for restoration and landscaping in the south is such that they cannot be used for replanting in the north. Most of the several million plants put into the ground at James Bay were green alder (*Alnus crispa*), planted to restore borrow pits, camp sites, erosion-sensitive zones, and sectors in which visual impact was noticeable. The replanting technique was well developed and its results were very significant.

Hydro-Quebec frequently has to perform restoration work in small areas in northern or very disturbed environments far from suitable plant production centres. Today, it is my intention to discuss one such case in particular.

THE WORK

The Site

The sector I wish to discuss is near the coast of Hudson's Bay at the Inuit village of Kuujjuarapik. Prior to 1983, Hydro-Quebec had carried out some work towards setting up a camp. There was no organic matter, as the site lay immediately on Hudson's Bay and the ground covering consisted almost entirely of sand.

A suitable technique for restoring this site and a type of plant had to be chosen in light of the location's particular features: its northern situation, its closeness to the sea, its exposure to high winds, its sensitivity to erosion, the texture and composition of the soil, the distance from plant production centres, and finally the fact that access was by plane only. It was also obviously necessary to find a restoration method that was economically acceptable.

Choosing a Restoration Method

The first step was to identify species that could be planted in this environment. Review of the literature and an inventory of vegetation in the area indicated that sea lyme grass (*Elymus arenarius* L.) would be suitable for our purpose.

Sea lyme grass is a large and very hardy stoloniferous plant found on the seashores of a number of countries. As it propagates by means of stolons, or runners, it invades and stabilizes the soil very rapidly. Although *Elymus arenarius* only grows in sea sand, other species such as *E. wiegandii*, *E. canadensis*, and *E. virginicus* that have similar properties could be used depending on the environment.

After debris was removed and the ground roughly levelled to prepare the site, several options were considered for introducing the sea lyme grass. One was to collect seeds at the appropriate time, conduct germination tests, keep the seeds, and produce young specimens under glass for planting the following year. Although valuable, this technique requires substantial financial outlay and a lot of time, while its results are almost entirely dependent on the plant's germination capacity.

Another solution was to reproduce the sea lyme grass vegetatively by using stolons to produce plants as hardy as those already growing at the site. Vegetative reproduction requires a sizeable infrastructure and significant amounts of time. Both techniques would be suitable for cases in which significant numbers of plants have to be produced.

However, given the restricted size of the sites to be restored, their northern location, the time constraints, and the machinery available, the most logical, most promising, and above all most economical technique was to introduce the sea lyme grass by replanting.

Work Methods

After debris was removed and the ground roughly levelled to prepare the site, three replanting methods were used:

- replanting clods
- individual replanting
- replanting clumps

Replanting Clods

A loader-type tractor was used to remove 2x2 m slabs of sea lyme grass from places where it was plentiful and where the impact of removing it would be minimal. These slabs were then hauled to the planting site in a trailer. Workers cut the slabs into clods about 30 cm in diameter before planting them approximately one meter apart.

This technique enabled us almost entirely to avoid damage to the roots during the transplanting operation, but the transportation from the extraction site to the replanting site and the handling proved limiting factors.

Individual Replanting

One crew removed plants from a site where the sea lyme grass grew in abundance, while pairs of employees replanted them one meter apart.

The plants were dug up individually to avoid damaging their roots, and kept in containers of water until replanting, so that the rhizomes would not dry out.

This technique can be performed very quickly, but requires great dexterity on the part of the employees digging up the plants, as the roots are very frail. The success of the transplanting operation obviously depends on the quality of the plants and the time lag between extraction and replanting.

Replanting Clumps

This operation is similar to that just described, except that the plants are planted in clusters usually consisting of three to five specimens.

Although a little slower than individual replanting, this technique minimizes error during extraction, and there is a greater probability that at least one plant out of a group will propagate.

Because it involves living material with bare roots, replanting of this type demands a relatively high level of care on the part of employees. Even though sea lyme grass is very hardy, a staff that works carefully and is aware of the potential problems can make all the difference between success and failure.

After the planting, the ground was covered with vegetable matter (straw) to stabilize the soil around the plants, and snow fences were erected on the windward side to minimize wind erosion. Notices were placed at strategic points to encourage local people to enter the site as little as possible.

Description of Work

The following data is offered as a guide only, as the work at

Kuujjuarapik was experimental in nature. It would be difficult to extrapolate from this project the level of productivity that could be achieved in large-scale projects.

Materials used - A loader-type tractor used to dig up the slabs of sea lyme grass and equipped with a trailer for hauling them to the planting site.

- Spades, buckets for transporting individual plants, straw, snow fences

The work was performed from July 12 to 19, 1983, over an area of about 2 ha.

Six native people were hired for the work period to dig up and replant the grass. One employee drove the tractor, and a foreman supervised the work.

RESTORATION RESULTS

Summer 1984 Results (1 year later)

A first evaluation in the summer of 1984 showed that the results of the restoration work were excellent. More than 95% of the plants had survived transplantation. Visual examination of individual plants showed excellent development of the root systems, and in several cases propagation by the rhizomes had begun. It is normal for the plant to develop a large root system during the first year rather than a stalk above ground.

Comparison of the three restoration techniques showed that none had a greater success rate than the others. There was a difference, however, in the visual effect: clods produced better coverage of the terrain than individual plants. On the other hand, wind erosion had tended to remove soil from the clods, and careful transplantation is therefore indicated.

The mulch did not give the results hoped for as it was quickly dispersed by the winds. The fences nevertheless appeared to have minimized the wind erosion and dissuaded the village residents from using the site.

Summer 1985 Results (2 years later)

A second assessment of the results, in the summer of 1985, revealed a number of points:

- The root systems of the sea lyme grass were becoming increasingly developed, especially in specimens planted individually or in clumps.
- Propagation by rhizome was more common among all the specimens. Up to ten secondary plants were found growing from one plant.
- There was a significant plant loss rate in one sector, the one most exposed to the dominant winds, and where vehicle

traffic appeared to have been common. Future visits will show whether the plants are completely dead or whether only the stalks are affected.

This second visit once again showed the excellence of sea lyme grass in establishing itself and invading the soil. It did, however, also indicate that this plant is very sensitive to human activity: terrain restored by means of this grass should be kept free of traffic.

Other plants associated with sea lyme grass were also found to be present, indicating the excellence of the replanting. These were:

Bluebell (*Campanula rotundifolia* L.)
Common yarrow (*Achillea millefolium* L.)
Fireweed (*Epilobium angustifolium* L.)
Green alder (*Alnus crispa* Ait.)
Three-toothed cinquefoil (*Potentilla tridentata* Ait.)

These plants were all found near the specimens replanted in 1983.

RECOMMENDATIONS

This experiment indicates how a number of disturbed northern sites should be managed. The work performed near native villages causes soil instability problems (earthworks, borrow pits, etc.). Although the species of plant may vary depending on the local environment and how far north the site lies, the following recommendations can be made:

- When earthworks are performed, islands of vegetation should always be reserved to serve later as a source of suitable plants.
- Fast-spreading species should always be used in restoration work, if possible that are already present nearby.
- Replanting appears to be qualitatively and economically preferable for projects involving small areas of land.

With respect specifically to sea lyme grass, we recommend the following:

- Choosing the replanting mode that best suits the visual effect and speed of propagation required.
- Always performing the work at the beginning of the growth season.
- Ensuring that the workers are conscientious and are given the minimum training for this type of work (work techniques, awareness of how to handle living material).
- Banning traffic from the site of work.

CONCLUSION

The technique of using sea lyme grass as a fast-spreading plant could be adapted for several other species used in northern Canada. It requires very little machinery, can easily be performed by locally hired people, allows use of plants adapted to the local environment, can be performed at very reasonable cost, and above all has a very good success rate.

It obviously has limitations: some plants withstand the shock of transplantation very poorly, so the species must be chosen with care.

The technique of replanting is however very advantageous for small areas of land and for regions where plant supplies are difficult to obtain.

Hydro-Quebec hopes that the sea lyme grass technique it has tested will be used elsewhere in Canada, and would be happy to share the experience it has acquired in the field of environmental restoration in the north.

CATTAIL STAND DEVELOPMENT ON BASE METAL TAILINGS AREAS

M. Kalin and R.G. Buggeln

Boojum Research Ltd.
Toronto, Ontario

ABSTRACT

Cattails are frequently one of the principal indigenous plants which colonize wet areas of tailings, whether on extremely alkaline surfaces or in highly acidic conditions. However the stands are often small and their expansion is limited to small sections of the tailings beach or only pockets of cattail stands on drier areas on the sites. The objective of the present work was to address expansion of existing cattail populations currently growing in these two contrasting pH environments associated with tailings areas.

Experiments were implemented to ascertain some of the factor(s) which controls cattail plant growth on the tailings areas belonging to Inco Ltd., Sudbury, Ontario, which were partially covered with pyrrhotite and partially with alkaline mine slimes. Other experiments investigated cattail stand expansion as well as methods of introducing cattails into areas where they were not currently growing.

A useful indicator of the potential for cattail stand to expand is the ratio of the number of juvenile individuals to the number of mature individuals around the stand perimeter. In cattail stands where rhizomes were deep and the waste material compacted, the ratio was about 0.2; in a stand where the rhizomes were shallow and overlying wastes were not compacted, the ratio was 0.5.

It was hypothesized that young growing juvenile shoots could not penetrate the hard, compacted layers of overlying wastes. A series of cultivation experiments were set up in August 1985 to test this hypothesis.

Mature cattail plants were successfully transplanted to 'vacant' areas on alkaline and acidic areas of the site. The parent transplants produced numerous juvenile plants such that the ratio of juvenile shoots to mature plants was 1.5, indicating a vigorous stand expansion potential in the alkaline areas. In acidic areas the cattail rhizome-root stocks were introduced hydroponically. The root crowns were anchored in the acidic creek (pH 2.5) and they produced shoots within 4 weeks. The plants overwintered both planted hydroponically and in the transplanted area. The transplanted populations doubled in the following growing season, whereas the hydroponics survived poorly.

Experiments with young cattail seedlings which had germinated in close proximity to the cattail stands, indicated that the majority of the seedlings perished before the end of the summer. However a combination of mulching and fertilizer treatments enabled seedlings to persist into the fall.

INTRODUCTION

Cattails are one of the principal indigenous plants colonizing tailings sites. The stands are however frequently limited to small areas, particularly on base metal tailings (Kalin, 1984). Under natural conditions cattail stand development is mainly controlled by hydrological factors. The hydrological conditions along tailings beaches do not differ drastically, although cattail stands are growing in patches. The objective of the work was to address growth controlling factors of cattails in two contrasting pH environments on a tailings site in the Sudbury area.

Site Description

The tailings are situated in a basin which is generally typical of many in the Canadian Shield. These basins are characterized by forested, undulating terrain with shallow soils overlying Precambrian bedrock, with numerous bedrock outcrops. The basin experiences the typical climate for the entire northern Ontario region, with mild summers and cold winters. The climate is generally humid with approximately 950 mm of precipitation each year. Winters are characterized by extensive snow cover, which results in considerable runoff each spring. The average annual evaporation is approximately 500 mm, leaving a net water surplus of 450 mm. This surplus either runs off or infiltrates into the groundwater.

The tailings area is 45 ha and is ringed by four containment dams. The surface of the tailings slopes along a line of one percent. Farther down the tailings surface, the slope is reduced to approximately 0.2%. Such slopes are common in tailings areas. The surface characteristics are of several types. Moist alkaline areas covering a large fan extend all the way to the shores of a mine water retention pond. Hard pyrrhotite cover and loose pyritic tailings are presently being revegetated.

Indigenous cattail stands have developed on the shores of the mine water retention pond and sparse pockets of stands are distributed in the alkaline mine slimes and along the edges of the acid surface creeks on the pyrrhotite. Water enters the tailings area naturally through incident precipitation and runoff from the surroundings. Milling and therefore tailings discharge has ceased for some time on that site and presently only the mine water is discharged to the tailings area, forming a waterlogged fan covering pyrrhotite with mine slimes.

MATERIALS AND METHODS

Cattail Stand Expansion

The perimeters of the stands were excavated in two manners. In the first method a total of about 15 cm of sediment was sequentially skimmed off in layers without disturbing the underlying sediments. In the second method, a 30 cm deep trench (=1 spade depth) was dug around the perimeter of the stand. The

sediments were broken up and the trenches were either completely backfilled or backfilled to within 15 cm of the surface. The sediments around the perimeter of control stands remained untouched.

Three square plots (approximately 4m x 4m) in the centre of a large stand were treated in different ways. One plot was flush-cut and raked free of cut cattails and debris. The entire plot was cultivated by hand with a spade to a depth of 30-40 cm. If rhizomes were brought to the surface they were dug into the loosened sediments. Two adjacent plots of similar dimensions served as controls: one was flush-cut and the cattails were raked off, the other received no treatment. The numbers of new shoots emerging from the 3 plots will be compared.

Transplanting Method

Mature cattails (vegetative and those bearing fruit stalks) were dug at random from cattail stands and planted in 6 groups of 10 plants. Each group was a circular to elliptical array, 3-5 m in diameter. Four of the stands were transplanted in early July and two stands in late July 1985.

Hydroponic Method

Cattails were dug from the bed of nearly 100% vegetative cattails in a cove of the mine water retention pond. The entire aerial (leafy) portion was cut off leaving the root crown, roots and any rhizomes, i.e. the underground stems which give rise to new juvenile plants. Eighteen cattail explants were placed about 0.3 m apart on a 6 m long, polyethylene net (2" mesh size) and laced into place with polyethylene line. Four such nets of explants were prepared. Two of them were installed along the shoreline of the minewater retention pond. A third array was placed across the mine slimes, recently accumulated behind a dam where mine slimes had accumulated covering pyrrhotite. The fourth array was anchored in a pool containing water of pH 2.5.

pH Determinations Around Cattail Roots

At three randomly selected cattail roots, mine-slimes-lime profiles were excavated from the root rhizome zone. 60 mL of sediments were placed in a beaker to which distilled water was added to a volume of 220 mL. The slime-water slurry was stirred with a glass rod while the pH and conductivity were determined.

Elemental Concentrations in Leaves

Cattail leaves and/or leaf tips were collected in September from the following locations on the tailings site: (1) an alkaline cattail stand (pH 9); (2) an acid cattail stand pH 2.5; (3) a nearly 100% vegetative stand and an adjacent fertile stand both alkaline; (4) was a collection made in a stand with high nickel concentrations and (5) a control site a natural stand, a quarter mile off Hwy 144 on a side road #65 leading to Rudder, Ontario.

Vegetative leaves from non-fruit producing cattails and

leaves growing around the inflorescence peduncle (fruit stalk) were collected. In addition, apical tips of leaves from the acid and alkaline stand were also harvested. The top 5-15 cm of the former was black; the leaf termini were brown coloured in the latter stand.

The leaf collections were dried at room temperature and then in an oven (150°C) for 30-60 min. They were ground in a Wiley mill to 20 mesh. ICP analyses for 18 metals and phosphorus were conducted after wet oxidation. Total C and total N (microkjeldahl) was determined from subsamples of the dried material.

RESULTS AND DISCUSSION

Cattail Stand Expansion

With regard to cattail stand expansion, we observed that a few of the cattail stands had a large number of juvenile plants, i.e. ranging in size from those which had barely pierced the sediment surface to plants < 30 cm tall. The majority of large and small stands, however, had comparatively few juveniles.

Regardless of the proximity of the cattail stands to the shorelines of the mine water pond the stands were not expanding. Only few juvenile shoots were being produced. Thus, it seemed reasonable to develop an empirical method whereby the bed expansion potential could be evaluated, that is, a measurement of the number of new plants divided by the number of mature ones.

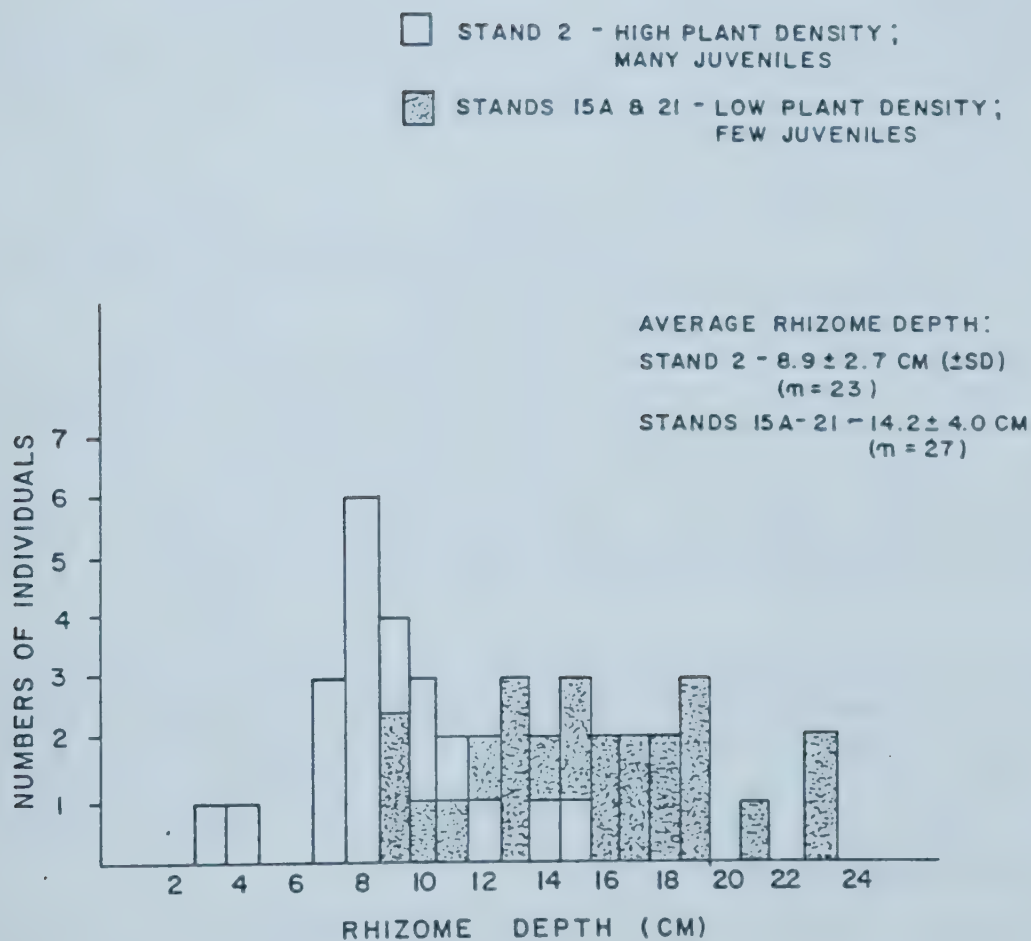
Juvenile-to-mature plant ratios were computed for 7 small cattail stands. The ratios are computed on the basis of all individuals in the stand resulting in an average of 0.2 or about 1 juvenile to 5 mature plants. The same ratio, counting just those individuals around the perimeter of the bed, is higher with 0.3 or 1 juvenile for every three adult plants.

It seemed obvious that in order for existing cattail stands to expand, the mature individuals had to be producing juvenile shoots. While juvenile shoots emerged some distance (10 to < 50 cm) from the parent plant in some stands new shoots frequently came up "cheek to jowl" along side the parent other stands.

These latter observations lead to the comparative study of rhizome depth and juvenile shoot production. The data are shown in the bar graph in Figure 1. The high juvenile-to-mature plant ratio exhibited a shallower rhizome depth and the lower ratio, a corresponding shift in rhizome position toward a greater depth. The average rhizome depth in stand 2 was 8.9 ± 2.7 cm (SD) while that in 15A and 21 was 14.2 ± 4.0 cm (SD).

During excavations to determine rhizome depths, we observed that layers of very compacted slimes and lime were encountered which gave a noticeable "resistance" to the spade and hand trowel. In many cases, we noted that the cattail rhizome with aborted shoot primordia lay just underneath the compacted sediment layers. By analogy, we concluded that if we encountered resistance while digging downward from the surface, surely young cattail shoots

Figure 1: Apparent Cattail Stand Expansion Potential and Rhizome Depth in Cattail Stands on Mine Slimes. (Stand 2 with many juvenile shoots has a high expansion potential and more shallow depth of rhizomes).



would be encountering similar resistance while trying to grow up toward the sediment surface through this compacted layer.

On excavating around the mature cattails in the latter stands, root-rhizome pH measurements were carried out. Table 1 gives the pH's of the mine slimes-limes around the roots and rhizomes of the cattails. They range from 8.5 to 9.9 with an average of 9.2. Of particular interest was a case in which the pH of the mine slimes in the vicinity of the parent plant was 8.5, while the pH, just 30 cm away, around the roots issuing from the rhizome of the parent was 4.6. The latter roots were actually growing into some fine pyrrhotite granules.

The results of the flushcut experiments and the expansions after over wintering were not encouraging. The marking of the perimeters did not survive the run-off and sedimentation of mine slimes sufficiently well to derive reliable numbers. The flushcut and excavation plots on the other hand yielded similar densities to those of the controls with 150 to 200 plants in all plots in September 1986.

Transplanting

A total of 6 new stands of cattails were started by transplanting plants from established beds (10 plants per new stand). In September, nearly 60 days after transplanting, only one of the initial 60 plants was dead and left behind no juvenile shoots. Table 2 gives the record of juvenile shoot production in each bed. The average ratio of juveniles to parent (irrespective of whether the parent was still alive in September) was 1.4. This ratio of almost one and a half juveniles per adult, is considerably higher than the juvenile-to-parent ratio reported from any of the established stands where ratios ranged from 0.2 to 0.5.

Although the high ratio may, in fact, be related to the physical act of disturbing the cattail plants and therefore may be considered as a result of a physiological "defense" mechanism which triggers accelerated rhizome growth and juvenile shoot production, the fact remains that the cattail transplanting experiment was successful. It does appear that transplanting cattails produced stands with a reasonable stand expansion potential and good survival rates.

The origin of the cattail pockets on the tailings areas might be related to cattail seedling survival. In July two small plots of young cattails were fertilized with regular garden fertilizer. Adjacent plots received no fertilizer treatment. No evidence of a positive benefit of the fertilizer could be visually detected after 33 days. However, after 60 days, young stands in the treated plots showed good green colour and ranged in height from 2.5 to 15 cm. In adjacent control plots, all the plants were dead.

Hydroponic Cattails

Hydroponic cattails did take root and new shoots were

Table 1: pH and Conductivity on Mine Slimes in the Root Zone

Cattail Stand #	Root-Rhizome Depth (cm)	pH	Conductivity mhos/cm ²
4	26	9.9	500
11	18 (23)	9.3 (9.7)	500
19	27	8.5	550
		4.6 *	800

* The rhizome from one parent root crown had its own root penetrating a layer of pyrrhotite. The latter roots were about 30 cm from the parent plant.

Table 2: New Juvenile Shoots (<30 cm) in Transplanted Cattail Stands in September 1985 and % Increase in September 1986.

Cattail Stand #	No. of Mature Juveniles		Ratio	No. Over- wintered	% Increase
6	10	8	0.8	8	238
7	10	15	1.5	9	200
8	10	13	1.3	8	162
10	10	11	1.1	7	200
16	9	14	1.6	6	m.1

m.1 marking lost on plants

produced by September 1985. However the survival after overwintering was very poor. Only two shoots continued to survive in the acid creek and none of the mine slime transplants. The nets were exposed due to extreme water level changes and hence no conclusion of the effectiveness of the method can be drawn.

The vast majority of young seedlings on the tailings had perished by the end of the summer. There were, however, notable exceptions. Isolated pockets of seedlings, well removed from established cattail stands, were healthy into September and were marked for observation in 1986. All seedling pockets, where the marking survived, grew in the following year. These observations indicate that potentially the origin of the cattail pockets are seedling populations which encountered conditions such that they could survive the initial critical establishment phase.

Metal Analysis of Cattail Leaves

Table 3 shows the metal content (ppm; mg/kg) for cattail leaves and cattail leaf tips. There are 5 paired leaf samples, i.e. leaves collected from plants in cattail stands from different locations, comparing the vegetative leaves (without the stalked "cattail" present) and leaves collected from the stalk bearing the brown cattail fruit.

Two collections of vegetative leaves were made from the stand of the mine water retention pond. One was from a population of exceedingly tall (about 2 m) cattails in which there were few fruit-bearing individuals. The second was from an adjacent population of short plants (<1.5m) with numerous fruit-bearing individuals.

Metal analyses on the cattail leaves were carried out to determine toxicity problems and nutrient limitations. Observation of leaves in the acidic stands suggested that the tips of cattail leaves (terminal 3-5 cm) were black. Frequently the outer border (1-2 mm) of either one or both edges of the leaves were also black. For cattails growing on the alkaline mine slimes, the tips were brown and occasionally there were brown edges to the leaves as well. Both colours, black and brown, indicated leaf cell death, but the "severity" of the toxicity problem appeared at least qualitatively greater in the acid-grown cattail leaves.

The quantitative mineral analyses (Table 3) indicate that substantial quantities of metals are absorbed by the cattails in the acidic stand. Especially significant are levels of Fe and S, when concentrations of these elements are compared with concentrations in the control leaves, i.e. acid creek is about 10 x the control value for Fe and 2.5 x the control value for S. The Fe content of the leaf tips of the acid creek cattails have 5 x the level contained in the entire leaf (on a dry weight basis).

It should be noted that on a dry weight basis, the tips concentrate many of the elements including Ni (91 ppm) and Mn (2,000 ppm). The tips of the alkaline (mine slime) cattails do as well, but to a much lesser extent, e.g. for Fe, 2 x the content of the entire leaf. Taylor and Crowder (1983a) mentioned similar

Table 3. CONCENTRATIONS OF SELECTED ELEMENTS IN CATTAIL LEAVES

CATTAIL CATEGORY/ LEAF TYPE	ELEMENT ¹ CONTENT (mg.kg ⁻¹ dry wt)										
	AL	B	CA	FE	MG	MN	P	S	CU	NI	ZN
<u>Control stand</u>											
Vegetative	41.8	5.9	10339	80.5	3871	861	1666	1613	7.8	2.6	11.1
Fruit stalk	54.4	6.4	13165	70.5	3958	1726	1618	1309	1.9	<4.8	13.0
<u>Alkaline water stand</u>											
Vegetative	92.5	6.8	9407	352	972	163	1828	3612	13.9	24.8	11.5
Fruit stalk	91.0	8.6	11063	338	899	171	1532	4309	14.0	32.7	10.7
<u>High Ni stand</u>											
Vegetative	34.6	6.3	3419	73	1471	279	1993	2168	5.1	69.1	11.4
Fruit stalk	45.5	8.9	6976	113	1384	717	2591	3510	3.9	74.5	9.9
<u>Acidic creek stand</u>											
Vegetative	37.3	9.5	9350	632	905	941	1315	3938	16.8	40.3	8.4
Fruit stalk	52.8	12.4	10669	575	986	1287	960	3065	2.9	35.9	7.6
Leaf tips ²	126.0	54.2	7681	3008	1155	2026	1230	5952	9.6	91.0	15.9
<u>Alkaline mine slimes stand</u>											
Vegetative	<19.0	5.5	12506	54.2	377	729	1253	1649	3.6	10.8	8.7
Fruit stalk	25.6	10.1	14036	64.7	190	762	814	1150	2.9	5.2	10.5
Leaf tips ²	40.4	55.7	11928	172	646	2958	1570	2039	9.1	<8.1	18.5
<u>Mine water stand</u>											
Vegetative											
All plants	<13.6	3.2	8944	63	566	385	1775	2703	7.3	13.3	12.2
Vegetative											
Short plants	<16.2	14.7	10663	70.2	505	113	1432	2266	5.8	10.1	11.7

- 1 - Elements concentrations below detection by ICP: As, Cd, Co, Pb, Se, and Te;
2 - Collected from both vegetative and fruit stalk leaves

leaf tip accumulation phenomena in their cattail studies.

As anticipated, the alkaline cattails growing on the mine slimes and those growing in mine water retention pond, had rather similar elemental concentration, e.g. Ni and Fe, but the former leaves had about twice the Ni content but little more than half the S content of the latter leaves. The high pH reduces the solubility of most of the metals, and they are, therefore, not "available" for absorption by the cattail roots. Generally, there were no consistent differences in trends in a comparison of the element content of vegetative versus fruit stalk leaves.

The dense stand of cattails in the mine water pond was exceedingly tall and healthy looking and the stand contained few fruit-bearing individuals. These cattails were as tall as those of the high Nickel stand, the alkaline water stand and the control stand. Boyd and Hess (1970) concluded from their study of cattail "standing crop", i.e. the biomass of weight of plants per m², that of all the nutrients in the hydrosols and water where the cattails were growing, only the P concentration was strongly correlated with biomass production. It is well known that mine tailings are very low in soluble P, particularly at alkaline pH's. It is of particular interest to note that the P content of the cattail leaves from this tall stand in the alkaline mine water pond is as high (or even higher than) as the P content from the other three locations.

In Table 4 selected elemental content of the acid creek water and the high Ni stand are compared to the elemental content of the leaves of its resident population of cattails. Because the uptake of elements by plants occurs via the roots, and the cattails are rooted in the sediments in the creek, it is not entirely justified to use elemental analysis of the creek water in the comparison with the elemental content of the cattail leaves. Such a comparison should be made using interstitial sediment water analysis (=pore water) which is present in the sediments because these are the concentrations of elements to which the plants are actually exposed. However it is assumed that the concentrations in the creek reflect closely the pore water concentration.

As opposed to the acidic creek stand all elements in the "High Ni" leaves are above the concentration of the element in associated water. Nickel concentrations in the leaves are highest, hence the name for the stand. The concentration factors for the acidic cattails (pH 2.5) are with the exception of Cu and P clearly lower than in the high Ni stand, with a more moderate pH value of 4.0. Although the concentration factors are negative for the acid creek population i.e. they indicate lower concentrations in the leaves than in the water, the absolute concentrations in the leaves are generally higher for those elements with negative concentration factors. Therefore it is suggested, that even under extreme acidic conditions, cattails are removing a fraction of the elements from the water to the biomass.

Bayley and O'Neil (1972) have reported that many elements show seasonal variations in their concentrations in cattails leaves. For example, Mg content has a midsummer peak. Such

Table 4: Comparison of the Concentrations of Selected Elements
the Acidic and High Ni Location and its Leaves

Element	Concentration		Conc. in leaves ¹		CF ²	
	Acid Creek (ppm)	High Ni	Acid Creek (ppm)	High Ni	Acid Creek	High Ni
Al	20.0	12.0	23.3	25.0	-0	+ 2.1
Cu	0.6	0.45	4.7	2.3	+ 7.8	+ 5.8
Fe	1232.0	3.3	312.9	48.1	- 3.9	+ 14.6
Mg	114.0	32.3	490.0	740.0	- 4.3	+ 23.0
Mn	8.0	2.1	577.0	258.0	+70	+122.9
Ni	26.0	0.45	19.7	37.2	- 1.3	+ 82.7
P	0.1	< 0.05	589.6	118.8	+5896	
SO ₄ ⁼	5292	539	1814	1471	- 2.9	+ 2.7
Zn	0.6	3.3	4.1	5.5	+ 6.8	+ 1.7

¹ Elemental data averaged for vegetative and fruit stalk leaves in Table 4; moisture content of 66% for cattail leaves as adapted from Kalin (1984) values for whole plants

² CF = concentration factor or relationship between elemental concentrations in the water and leaves; (+) leaves > water; (-) water > leaves

seasonal dynamics of mineral nutrients are found in all perennial plants, but those were not addressed in this study.

Carbon and Nitrogen Status of Cattail Leaves

The carbon and nitrogen content (C and N as % dry weight) for the samples of cattail leaves from a number of sites is given in Table 5. It is immediately evident that the leaves in all stands have essentially similar carbon contents, i.e. 47-48%. The C content of the vegetative and fruit stalk leaves is also essentially similar.

There is a rather wide range in nitrogen values: from 1.0 for the fruit stalk leaves of the controls to 2.5% for the vegetative "short" plants from mine water stand. Grouping the vegetative leaf N values according to the qualitative distinction of whether the plants are tall with long leaves or short with short leaves, i.e. the control, the alkaline water stand and mine water stand "tall" plants versus the remaining 3 locations, respectively, there is no separation of % N values. In both groups the values range between 1.5 and 2.0 (2.5)% N.

The carbon to nitrogen ratio of plant organic matter is only a useful index if it can be empirically determined that there is a consistent relationship between the numerical value of the ratio and some biological or ecological factor. In the present case, we have grouped the cattail sites into those showing a vigorous plant growth (tall plants; long leaves) and stunted plant growth (short plants; short leaves). The C:N ratios are shown in Table 5 and it may be noted that, as with the %N (and %C), the two groupings of plants cannot be related to a similar grouping of C:N ratios. For the tall plant category, the C:N ratios ranged from 21 to 28; for the short plants, from 16 to 32.

On the basis of the comparative N analyses, it does not appear that cattail growth on the alkaline mine slimes, in the acid creek or in the mine water stand (short plants), are limited by N. It is interesting to note that the %N in the tall and short plant populations is essentially similar, with the latter only slightly higher than the former. There is a considerable difference in the C:N ratios because the C content in the short plants is 5% lower than in the tall plants. Carbon metabolism in plants is dependent on "high energy" phosphorus. In Table 2 the P content of the mine water stand, i.e. short plants (1,432 ppm) is lower than that in tall plants (1775 ppm).

The %C cannot be correlated with plants grouped according to their stature, but the P content of vegetative leaves can be related to the tall vs. short plant groupings (see Table 2). While the foregoing considers nutrient limitations, especially P, as the element which may be limiting growth of cattail, it is also possible that cattail growth is inhibited by an interaction of heavy metals and, in the case of the acidic creek the lower pH of the water as well.

Table 5: Carbon and Organic Nitrogen Analysis of Cattail Leaves

Carbon and Nitrogen as % Dry Weight			
	% Carbon	% Nitrogen	C:N Ratio
Control Stand			
Vegetative	42.0	1.5	28.0
Fruit Stalk	46.8	1.0	46.8
Alkaline Water Stand			
Vegetative	48.1	1.7	28.3
Fruit Stalk	48.0	1.5	32.0
High Ni Stand			
Vegetative	48.3	2.0	24.2
Fruit Stalk	49.0	2.2	22.3
Acidic Stand			
Vegetative	47.4	1.8	26.3
Fruit Stalk*	47.5	1.3	36.5
Leaf Tips	48.9	2.0	24.5
Alkaline Mine			
Slimes Stand			
Vegetative	48.3	1.5	32.3
Fruit Stalk*	47.0	1.0	47.0
Leaf Tips	47.2	2.5	18.9
Mine Water Stand			
Vegetative Tall			
Plants	45.2	2.1	21.5
Vegetative Short			
Plants	40.1	2.5	16.1

* collected from both vegetative and fruit stalk leaves

SUMMARY

The expansion of mature cattail stands growing alkaline mine slimes appears to be inhibited in those areas where there has been accumulation and packing of layers of mine slimes and lime (Figure 1) reflected in the differing rhizome depths. Mature cattails growing on mine slimes were successfully transplanted to areas of the mine slimes which were devoid of cattails. Frequently the leafy portion died, but new shoots arose from the subterranean rhizome.

Metal analyses of cattail leaves showed that plants growing in the acid creek accumulated a considerable level of Fe and S. The "tall" population of cattails in the mine water stand had a higher P content than all other populations investigated. None of the cattail stands seem to be deficient in N. However, phosphorus content of the cattail leaves suggests that the acid creek and alkaline cattails are P-limited in comparison with the "tall" stand of cattails in the mine water pond.

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ECONOMIC AND BIOLOGICAL FEASIBILITY OF
NATIVE PLANTS FOR LAND RECLAMATION
IN WESTERN CANADA

Carol E. Jones

C.E. Jones and Associates Ltd.

Bruce McTavish

Reid, Collins Nurseries Ltd.

INTRODUCTION

The feasibility of using native plants for land reclamation should be addressed from both a biological and an economic perspective. For a species to be biologically feasible for use in reclamation it must be readily propagated. Propagation from seed can involve various methods of dormancy breaking while propagation from cuttings usually involves hormone treatments. Once growth is established through rooting or germination, favourable heat, light, moisture and soil conditions must be provided in the nursery to promote rapid growth.

For native plants to be economically feasible, the long run costs must be less than or equal to alternate methods of reclamation, or they must provide a greater benefit for their increased cost. The direct comparison of costs between reclamation methods is complicated by the difficulties of assessing the cost benefit of the end land use.

The use of native trees and shrubs in reclamation increases the wildlife habitat value of the land. In general shrubs are higher in crude protein, phosphorus and calcium than grasses and forbs. Trees and shrubs also maintain their nutritive value throughout the growing season and in many cases are critical for wildlife survival in snow covered winter ranges. They also provide more diversity of habitat than those sites reclaimed with only agronomic species.

The aesthetics of reclaimed sites is enhanced by the planting of trees and shrubs. This is especially important in areas of high public visibility. In these areas trees can provide screening and buffer zones which cannot be accomplished through the use of a grass and legume cover.

In many cases native trees and shrubs are better adapted to harsh sites than agronomic species. Native species usually establish quicker and provide much deeper rooting and thus better erosion control than an agronomic cover.

A summary of the criteria for selection of woody species for reclamation purposes is shown in Table 1.

PROPAGATION

Propagation by Seed

The seeds of most species from northern climates exhibit varying degrees of physical and physiological dormancy which must be overcome to achieve successful germination.

Physiological dormancy is related to the physiological conditions of the anatomically mature seed (Krugman *et al.*, 1974). This dormancy can be due to chemical germination inhibitors, restricted respiration, changing levels of enzyme activities or a variety of other underlying causes.

Physical dormancy is due to morphological conditions of the

Table 1: Selection Criteria for Woody Species Used in Reclamation (from Sherlock, 1983).

Criteria	Comments
1. Native/Naturalized	Adapted to local climate Adapted to wide range of sites
2. Pioneer species	
3. Success on other sites	
4. Rapid juvenile growth	Rapid initial ground cover
5. Provide food and cover for wildlife	
6. Withstand browsing and grazing	
7. Ease of propagation	Produce on commercial scale
8. Commercial value	Value as forest products
9. Nitrogen fixing ability	
10. Contributes to end land use	
11. Disease and pest resistant	

seed which prevent germination (Krugman *et al.*, 1974). The most common reasons for physical dormancy are immature embryos, hard seed coats, or some structure such as an endocarp which prevents germination (Krugman *et al.*, 1974).

Methods of Dormancy Breaking

The most common and efficient method of breaking dormancy due to hard seed coats is immersion of the seed for varying lengths of time in concentrated sulfuric acid. The length of time is based on the thickness of the seed coat, which must be constantly monitored to ensure that embryo damage does not occur.

The usual method for overcoming physiological dormancy is through the use of varying types of stratification. Stratification is normally carried out by pre-soaking the seed for 24 hours in water then placing the seed in cold storage at 2 to 3 °C for periods of several days up to six months. The seed is usually placed in a medium, such as peat or sand, to maintain high moisture levels. Alternatively, naked stratification may be used which requires much closer monitoring of moisture levels. Additionally, some species such as *Rosa acicularis* require a period of warm stratification followed by a period of cold stratification. The method for warm stratification is similar to gold stratification except temperatures are maintained at 20 to 25 °C.

Table 2 shows a number of native species and their germination success with various stratification procedures.

Vegetative Propagation

Several species of trees and shrubs propagate easily from both hardwood and softwood cuttings. In some genera such as *Salix* and *Populus*, cuttings are the preferred method of propagation. In general, cuttings must be treated with a root stimulating hormone, usually indolyl-butyric acid, although occasionally indolyl-acetic acid based compounds are used. For efficient rooting of most species bottom heat is required at 18 to 20 °C. With softwood cuttings, overhead misting or fogging is necessary until substantial rooting has taken place. Table 3 shows the rooting results of several species propagated from softwood and hardwood cuttings.

Growth Media

Species used in reclamation originate in a variety of different climates and have different nutrient and pH requirements. For these reasons greenhouse conditions and growth media must be modified to suit the individual species.

In general the logistics and economics of growing plants on a large commercial scale necessitate the division of plants into wet or dry climates and acidic or basic soils.

In most cases the drybelt species also require higher pH media and the wetbelt species require lower pH media. The growth

Table 2: Effectiveness of Seed Pretreatments on Various Native Species

Species	Treatment	% Germination
<i>Alnus crispa</i>	21 d CS	70 - 90
<i>Amelanchier alnifolia</i>	90 d CS	80 - 90
<i>Artemesia tridentata</i>	120 d CS	50 - 60
<i>Arctostaphylos uva-ursi</i>	1 hr. A, 90 d CS	45 - 60
<i>Cornus stolonifera</i>	90 d CS	80 - 90
<i>Eleagnus commutata</i>	120 d CS	80 - 90
<i>Juniperus communis</i>	2 yr. Alt. WS & CS	50 - 60
<i>Penstemon fruticosus</i>	120 d CS	40 - 50
<i>Potentilla fruticosa</i>	90 d CS	75 - 85
<i>Prunus virginiana</i>	30 d WS 90 d CS	60 - 70
<i>Rosa acicularis</i>	60 d WS 60 d CS	70 - 80
<i>Rosa woodsii</i>	60 d WS 60 d CS	70 - 80
<i>Shepherdia canadensis</i>	5-7 min. A, 10 d CS	80 - 90

Abbreviations:

A: Acid scarification, soaking seed in concentrated sulfuric acid

CS: 24 hour soak in water followed by storage at 2 to 3 °C

WS: 24 hour soak in water followed by storage at 20 to 25 °C

Table 3: Success in Rooting of Various Species Propagated by Vegetative Means

Species	Cutting	Treatment	Rooting %
<i>Amelanchier alnifolia</i>	H or S	#2 and #3	2 - 5
<i>Cornus stolonifera</i>	H	#2	75 - 80
<i>Cornus stolonifera</i>	S	None	85 - 90
<i>Juniperus communis</i>	H or S	#2 and #3	50 - 60
<i>Populus</i> sp.	H	None	90 - 95
<i>Rosa acicularis</i>	S	#1	90 - 95
<i>Salix</i> sp.	H	None	90 - 98

Abbreviations:

H: hardwood cutting
S: softwood cutting
#1: 0.2% IBA rooting powder
#2: 0.4% IBA rooting powder
#3: 0.8% IBA rooting powder

media is therefore relatively constant except for the addition or deletion of lime to adjust for pH. The majority of growing media are based on a combination of sterilized peat, vermiculite, perlite, micronutrients, slow release fertilizer, and lime.

RESULTS OF RECLAMATION RESEARCH WITH NATIVE PLANTS

Results of reclamation research trials of native plant species are presented from three mines in Western Canada. These mines occur in widely different climates and produce quite different types of waste materials. Lornex Mining Corporation Ltd. operates an open pit copper and molybdenum mine located in the south-central interior of British Columbia, approximately 80 km south-west of Kamloops. It is located in the Ponderosa Pine and Douglas Fir section of the Montane Forest Region (Rowe, 1972). Suncor Limited is an oil sand mine located in north central Alberta, approximately 40 km north of Ft. McMurray. This mine occurs in the northern portion of the Mixedwood section of the Boreal Forest Region (Rowe, 1972). Pine Point is a lead and zinc open pit mine operated by Cominco Ltd. in the Northwest Territories. The mine is located in the Upper Mackenzie Section of the Boreal Forest Region (Rowe, 1972), approximately 80 km east of Hay River.

In our experience in reclamation with native species, each mining area has significantly different site conditions which require an initial research phase to determine species suitability. The definition of suitable candidate species is often followed with further research into methods of site preparation and planting stock. Research results from a selection of mines is presented here to better illustrate this progression in reclamation research programs.

Lornex

Native plant studies were initiated in 1983 for use in reclaiming both waste rock and tailings materials. An assessment of vegetation colonizing natural coarse rock slopes in the area led to the development of a list of candidate species for the waste rock trials. Natural sites comparable to the tailings deposit were not available for assessment and therefore species were selected for use in the tailings trials based on experience with other tailings deposits, laboratory analysis of the materials and a knowledge of the regional plant communities.

Trials were planted in 1984, in a completely randomized plot design. Ten seedlings comprised one plot and each plot was replicated three times. Table 4 presents the percent survival after one year of each of the nine species planted in the waste rock trials. Two trial areas were established on waste rock and the values in this table represent mean survival from the two areas. Results of the survival of eleven species planted in the tailings trial are given in Table 5.

These results indicate that a shrub community could be established on both the waste rock and the tailings materials. Some species, such as *Salix* spp., *Artemesia tridentata* and *Rosa*

Table 4: Survival of Native Species Planted in Waste Rock at Lornex Mines.

Species	Survival (%)
<i>Salix</i> spp.	98
<i>Rosa</i> spp.	83
<i>Artemesia tridentata</i>	80
<i>Clematis ligustifolia</i>	75
<i>Amelanchier alnifolia</i>	63
<i>Arctostaphylos uva-ursi</i>	55
<i>Shepherdia canadensis</i>	38
<i>Potentilla fruticosa</i>	35
<i>Pinus contorta</i>	25

Table 5: Survival of Native Species Planted in Tailings at Lornex Mines

Species	Survival (%)
<i>Salix</i> spp.	90
<i>Eleagnus commutata</i>	87
<i>Artemesia tridentata</i>	66
<i>Pinus contorta</i>	63
<i>Rosa</i> spp.	56
<i>Arctostaphylos uva-ursi</i>	43
<i>Potentilla fruticosa</i>	33
<i>Penstemon fruticosus</i>	30
<i>Shepherdia canadensis</i>	17
<i>Clematis ligustifolia</i>	10
<i>Amelanchier alnifolia</i>	7

spp. are suitable candidates for both the waste rock and tailings areas, while others such as *Amelanchier alnifolia* and *Pinus contorta* were much more successful on waste rock than on tailings. Species with low survival values will not be considered in further trials.

Once an initial screening of candidate species is complete, efforts are concentrated on defining the site treatments most suitable for native plant establishment and growth. One consideration is the effect of competition for moisture and nutrients between the seedlings and a grass and legume ground cover. At Lornex Mines, two trials have been established to assess the effect of this competition.

On the tailings, a trial of five species was planted into areas of established agronomic cover and into bare tailings. The experimental design was similar to that described previously. Results of this trial are presented in Figure 1. Some species, such as *Artemisia tridentata* and *Rosa acicularis* were found to have increased survival rates when planted with a ground cover. The other species experienced the opposite effect and had reduced survival rates when in competition with an agronomic cover.

The effect of competition from a grass and legume cover on *Pinus contorta* seedlings was tested on both waste rock and till covered waste. In this trial, ground cover was reduced by withholding maintenance fertilizer. Results of this trial, shown in Figure 2, demonstrate a different response to ground cover on the waste rock site as compared to the till covered site. In the waste rock, the survival of *Pinus contorta* seedlings was increased through reduction of ground cover. The till covered site experienced only a slight reduction of ground cover due to the lack of fertilizer application, however, the reduced nutrients may have negatively affected the percent survival of *Pinus contorta* seedlings. This suggests that on the waste rock, where moisture availability is critical, reduced plant competition can increase seedling survival. Others (Grossnickle and Reid, 1984), have found a grass cover on mine wastes in areas of high solar radiation and low soil moisture levels can reduce the soil moisture availability in the upper portion of the soil profile. This cover also increases the soil and air temperatures around the conifer seedlings, negatively affecting their establishment and growth.

Suncor:

Research at Suncor has assessed the survival of native species when grown in varying degrees of ground cover. The data presented here is a portion of a larger study which began at Suncor in 1980. Figure 3 presents the results of a trial in which six native tree and shrub species were planted into two ground cover treatments (McTavish and Shopik, 1983). Most species tested, *Populus balsamifera*, *Cornus stolonifera*, *Amelanchier alnifolia*, and *Potentilla fruticosa*, were found to respond negatively to a dense ground cover, however *Picea glauca* and *Prunus virginiana* had increased survival when planted into a dense cover. As a result of this trial and others, Suncor has concluded

FIGURE 1

EFFECT OF GROUND COVER ON

SPECIES SURVIVAL AT LORNEX TAILINGS

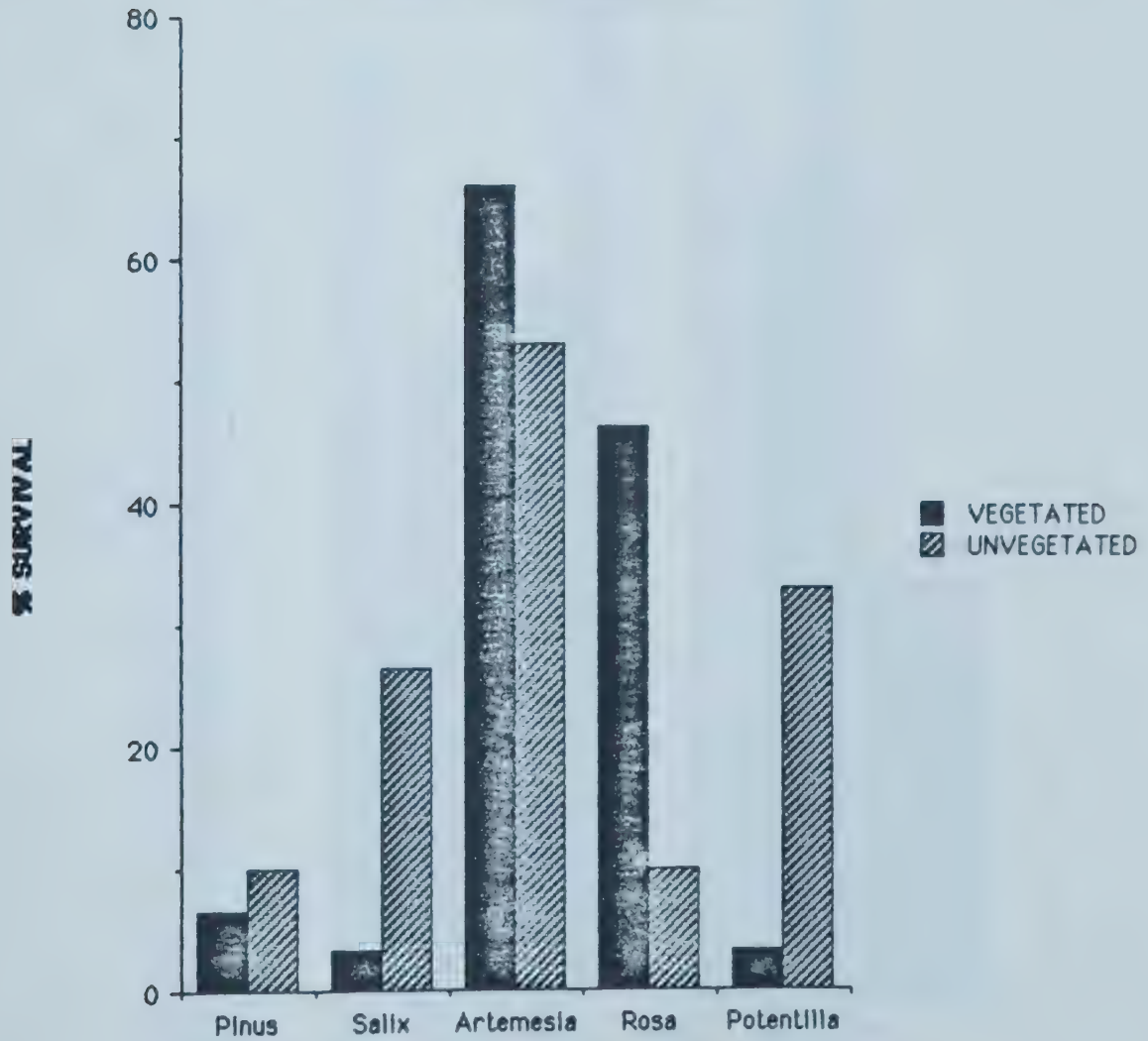


FIGURE 2

EFFECT OF GROUND COVER ON
PINUS CONTORTA SURVIVAL AT LORNEX

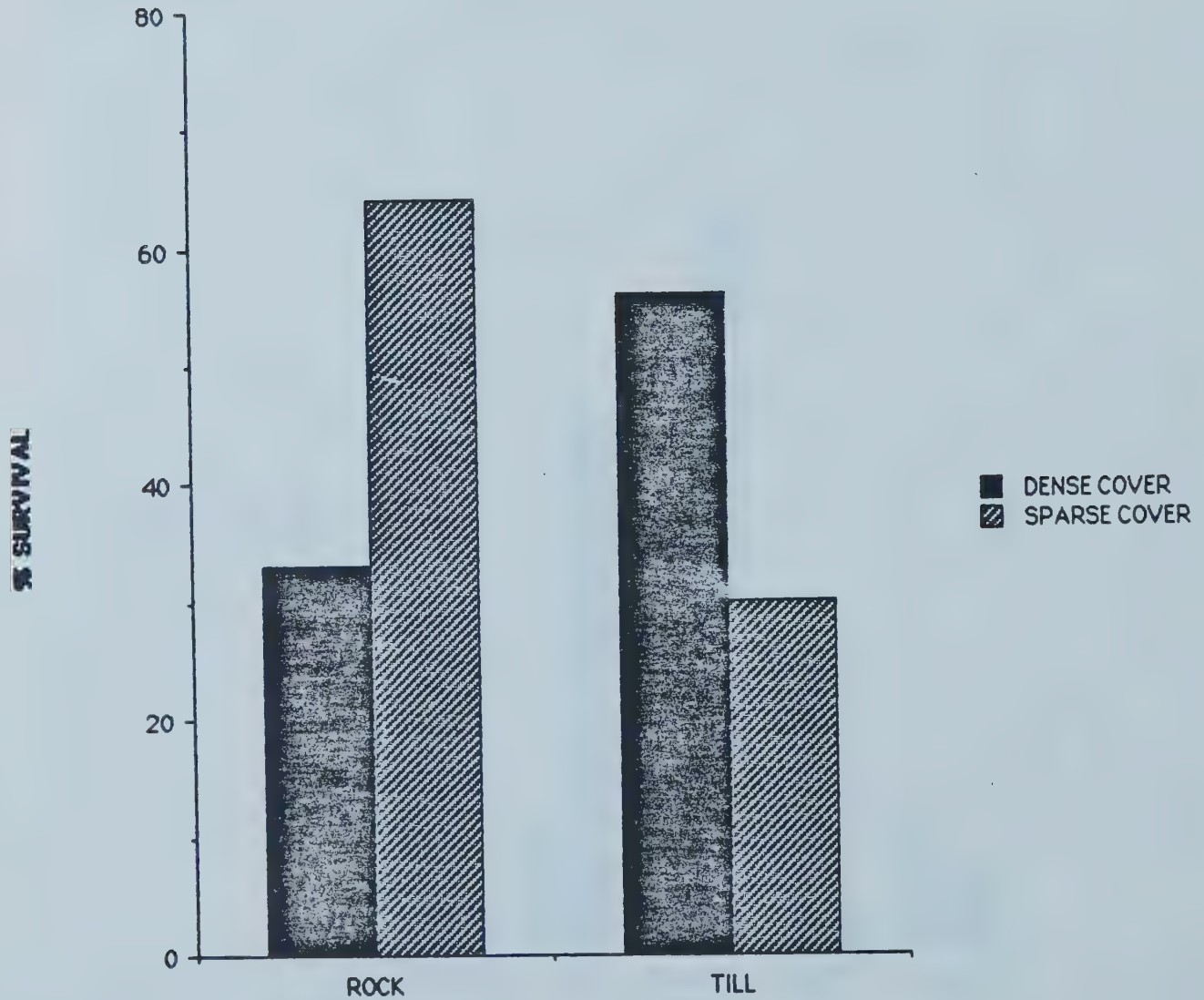
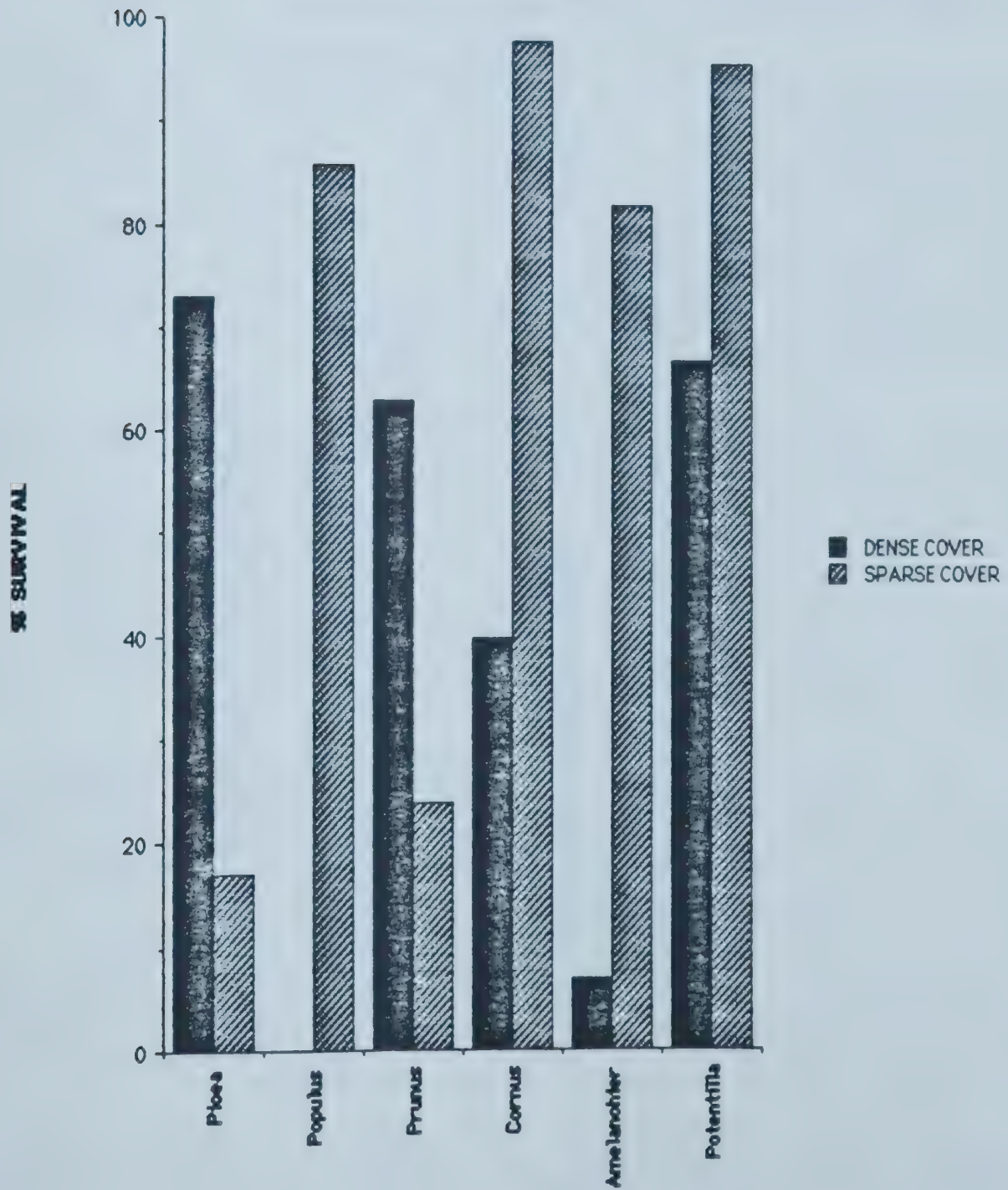


FIGURE 3

EFFECT OF GROUND COVER

ON SPECIES SURVIVAL AT SUNCOR



that for the best reclamation success at their minesite, woody species should be planted into a sparse ground cover (McTavish and Shopik, 1983).

Pine Point

At Pine Point, Mr. Bob Gardiner has established long term reclamation trials using native species. In addition to selection of candidate species and monitoring planting conditions, Gardiner has assessed the effect of seedling age and provenance on the percent survival of the native species.

In a long term trial on mine waste at Pine Point, Gardiner has compared the survival of seedlings planted at one and two years of age. Figure 4 presents the results of this trial, assessed six years after planting. Some species, *Rosa acicularis* and *Shepherdia canadensis* show little or no difference in survival between the two seedling ages. Others, *Populus tremuloides* and *Potentilla fruticosa* had much greater survival when planted at two years of age. This difference is due in part to the limited rooting which can be achieved in *Populus tremuloides* cuttings after one year of growth. Species which are slow to produce roots from cuttings are often grown on in the nursery for an additional year before planting on site.

In another trial, three species were grown from two seed sources, one collected from the locality of the Pine Point mine and the other source from Ft. McMurray, Alberta, approximately 550 km to the south. The species tested were *Rosa acicularis*, *Potentilla fruticosa*, and *Pinus banksiana*. The trial was established in September 1982 and the results presented in Figure 5 are of an assessment made in July, 1985. The results of this study indicate that the source or provenance of the seed does effect the survival of the seedlings, particularly of *Pinus banksiana*. The importance of seed provenance is well known in forestry applications and this study confirms its value in land reclamation.

The research projects discussed here give only a brief overview of some of the work in progress at many western Canadian minesites. They do however demonstrate the approach taken by many researchers in determining the most advantageous use of native plant species in site specific applications in mine reclamation.

COSTS ASSOCIATED WITH USE OF NATIVE PLANTS

The comparison of costs between reclamation methods is complicated by the difficulty in comparing end land use benefits. For this reason only the direct costs of planting under varying conditions are given in Table 6. No attempt is made to analyze the cost/benefit of different reclamation methods.

The cost comparisons are all based on planting Spencer Lemaire Hillson containers. Two methods are used for planting depending on the site, either an auger method or a mattock planting. The auger method utilizes four inch diameter carbide tipped augers mounted on chainsaw engines to drill holes for

FIGURE 4

EFFECT OF SEEDLING AGE ON
SPECIES SURVIVAL AT PINE POINT

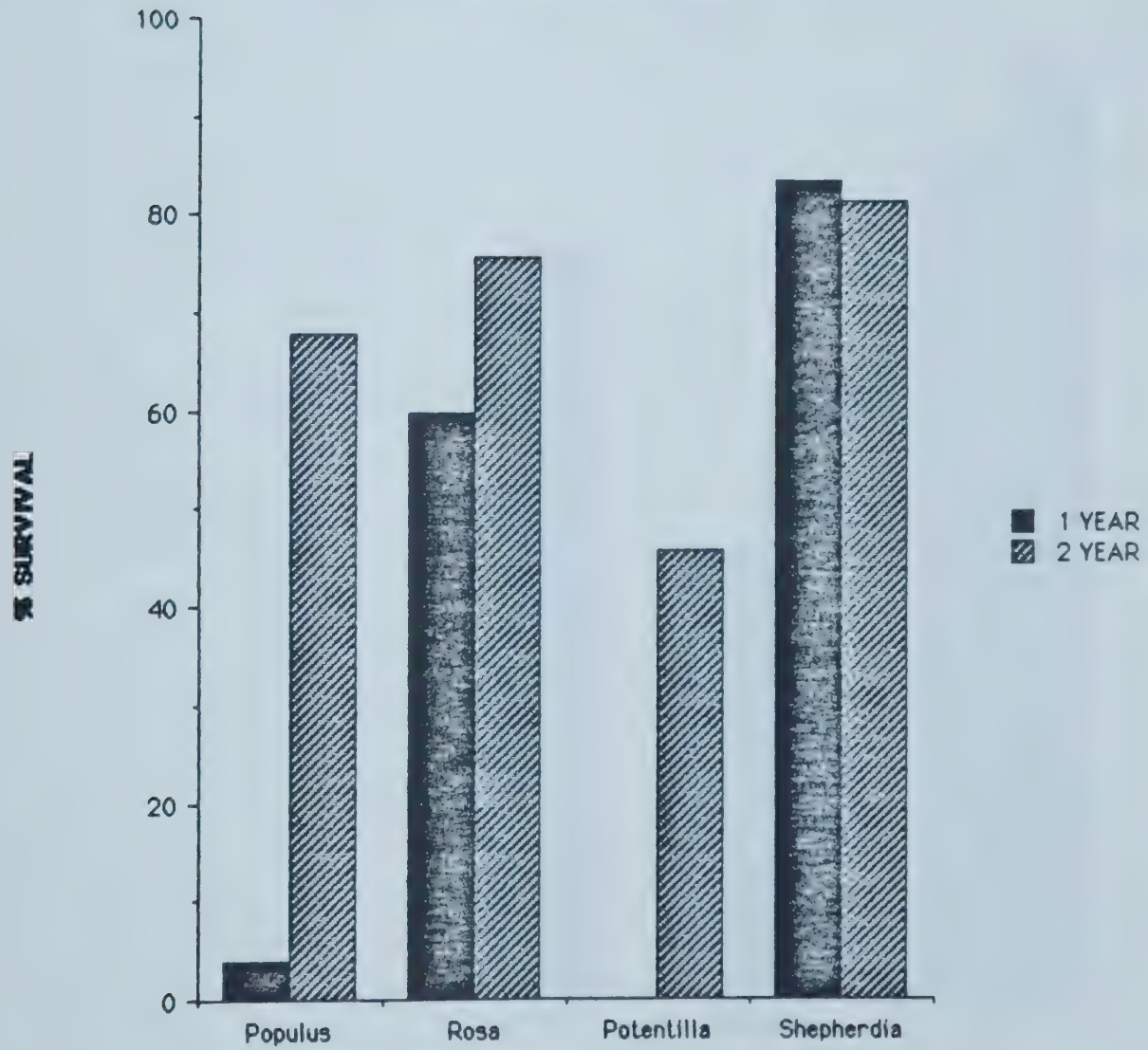


FIGURE 5
EFFECT OF PROVENANCE ON
SPECIES SURVIVAL AT PINE POINT

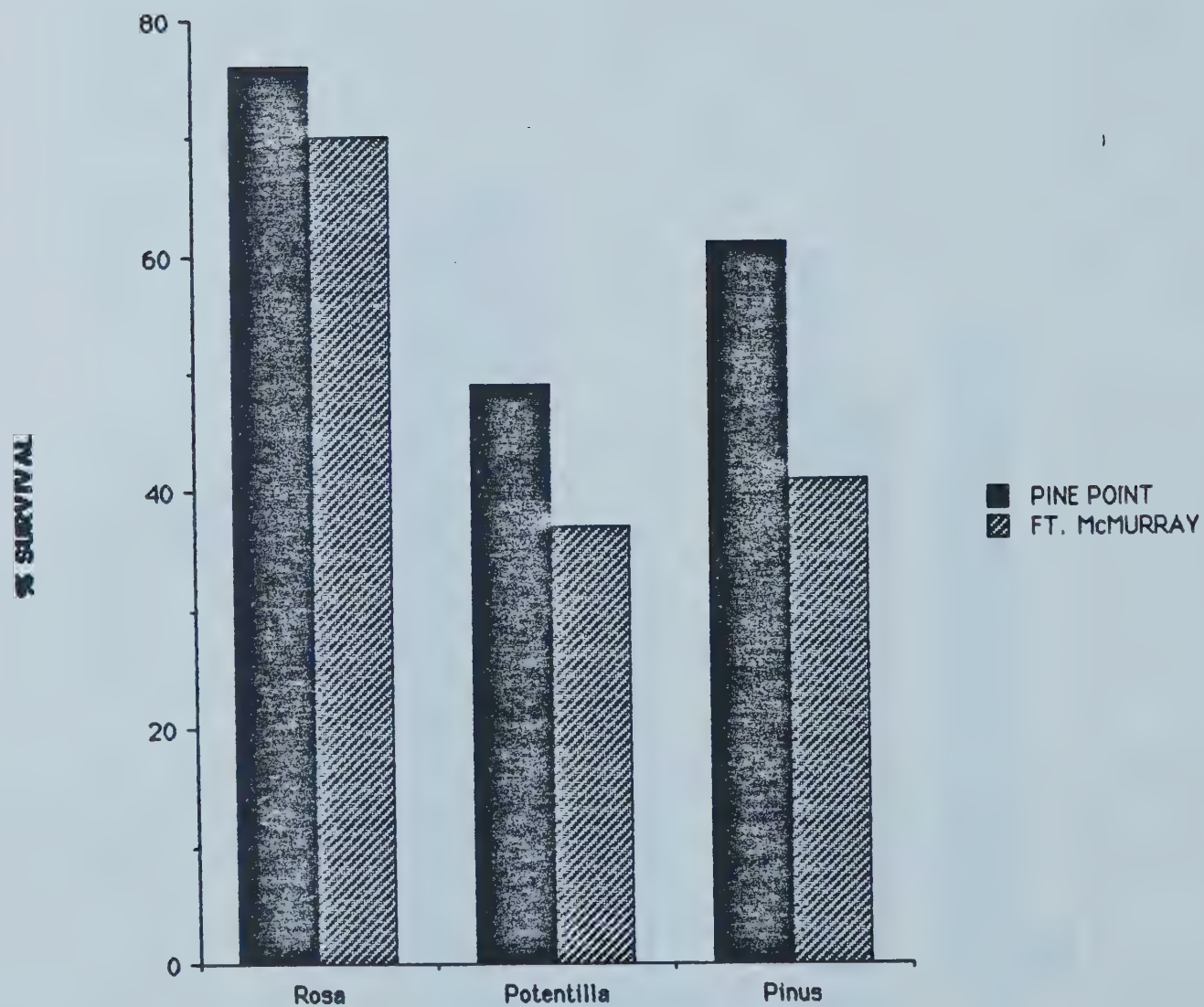


Table 6: Costs of Planting Woody Species on Various Sites

Reclamation Site	Planting Density	
	3000 stems/ha	6000 stems/ha
*Hard rock mines resloped waste rock	\$2600	\$5200
*Coal mines/Oil sands	\$2010	\$4020
*Road sides, slopes 2:1 or less	\$1860	\$3720
*Avalanche slopes steep road sides 1.5:1 or greater	\$3200	\$7300

All prices based on one year old seedlings in 10 cubic cm containers. Base price of \$0.37 per seedling.

planting. The use of augers is particularly effective on coarse or compacted waste rock where traditional mattock planting methods are impossible or at best very difficult.

On hard rock mines with resloped waste rock the rate of planting can vary from three hundred to five hundred plants per day per person depending on site specific conditions. On coal mines and oil shales the sites are generally less coarse and compacted than on hard rock mines and therefore planting efficiency is improved. On these sites planting rates should vary from six hundred to eight hundred stems per man day. On road sides with reasonable slopes and soil conditions planting rates can vary between seven hundred and one thousand stems per man day. Our experience on extremely steep slopes such as avalanche tracks has indicated that planting efficiency can drop to two hundred to three hundred stems per man day.

In general, to determine the cost of the installation of plant material, the density of planting, site specific soil and slope conditions and on-site transportation logistics must all be considered. In addition the cost of the supply of the plant material from either a commercial nursery or an in-house nursery operation must be added.

If the plant material has been well selected and planted properly there should be no subsequent maintenance costs for refertilizing or reseedling. This should allow the mine operator to complete final reclamation without concern for follow up maintenance procedures that may be necessary when agronomic grasses and legumes are used.

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APPENDIX 1: List of Registrants

Dr. A. Abboud
Alberta Research Council
6th Flr, 4445 Calgary Tr. S
Edmonton, Alta
T6H 5R7

Gerald Acott
Environmental Coordinator
Cardinal River Coals Ltd.
Bag Service 2570
Hinton, Alta. T0E 1B0

Alex Ansell
Environmental Specialties
Ontario Hydro
700 University Avenue
Toronto, Ont. M5G 1X6

Dr. Peter Beckett
Biology Department
Laurentian University
Sudbury, Ont.
P3E 2C6

Roger Berdusco
Fording Coal Ltd.
P.O. Box 100
Elkford, B.C.
V0B 1H0

Dr. W.W. (Bill) Carr
Terrasol
P.O. Box 2092
Vancouver, B.C.
V6B 3T2

Dr. Dale W. Cole
Associate Dean
Coll. of Forest Resources
University of Washington
Seattle, Wash. 98195

Steve Crampton
Sales Representative
American Excelsior Co.
609 South Front St.
Yakima, Wash. 98901

Gerry Davis
Soilcon Laboratories
805 West 10th Avenue
Vancouver, B.C.

Cheryl Dawson
Dawson Seed Co. Ltd.
104 Charles Street
North Vancouver, B.C.

Ralph Dell
Supervisor, Landscape Op.
Ont. Min. Transp. & Commun.
1201 Wilson Avenue
Downsview, Ontario M3M 1J8

Dave Easton
B.C. Transit
2992 Gravely St.
Vancouver, B.C.
V5K 3K3

John Errington
Min. of Energy, Mines &
Petroleum Resources
Parliament Buildings
Victoria, B.C. V8V 1X4

Dr. R. Fessenden
Terrain Sciences Dept.
Alberta Research Council
6th Flr, 4445 Calgary Tr. S.
Edmonton, Alta. T6H 5R7

Joe Fitzpatrick
Soil/Reclamation Specialist
3678 Rutherford Cres.
North Vancouver, B.C.
V7N 2C7

Murray Galbraith
Min. of Energy, Mines &
Petroleum Resources
Parliament Buildings
Victoria, B.C. V8V 1X4

Francois Gauthier
Hydro-Quebec
800 est, boul de Maisonneuve,
16e etage
Montreal, QC H2L 4M8

Kathy Gould
Dept. of Soil Science
2357 Main Mall
Univ. of British Columbia
Vancouver, B.C. V5T 2A2

Coleen Hackinen
Dept. of Soil Science
2357 Main Mall
Univ. of British Columbia
Vancouver, B.C. V5T 2A2

Dr. C.L. Henry
Sludge Research Program Dir.
College of Forest Resources
University of Washington
Seattle, Wash. 98195

Darlene Hergott
Landscape Designer
Professional Gardener Co. Ltd.
915 - 23rd Ave S.E.
Calgary, Alta. T2G 1P1

R.N. Hitchman
Instructor, B.C.I.T.
3700 Willingdon Avenue
Burnaby, B.C.
V6G 3H2

Stephen Homoky
Research Branch,
Ministry of Forests
31 Bastion Square
Victoria, B.C. V8W 3E7

Carol E. Jones
C.E. Jones & Assoc. Ltd.
2054 Northbrook Drive
Sidney, B.C.
V8L 4J5

Margarete Kalin
Research Director
Boojum Research Ltd.
139 Amelia Street
Toronto, Ont. M4X 1E6

Al Kennedy
Environmental Coordinator
Esso Resources Canada Ltd.
237 - Fourth Avenue S.W.
Calgary, Alta. T2P 0M6

A. Lannon
Manager, Environmental Affairs
Canada Cement Lafarge Ltd.
6150 Royalmount
Montreal, P.Q. H4P 2R3

Dr. L.M. Lavkulich
Department Head
Dept. of Soil Science, U.B.C.
2357 Main Mall
Vancouver, B.C. V6T 2A2

Gerry Lee
Lands Directorate, Env. Canada
20th Flr, Place Vincent Massey
351 St. Joseph Blvd
Hull, P.Q. K1A 0E7

Tony Lenard
Sales Representative
American Excelsior Company
609 South Front Street
Yakima, Washington 98901

Leonard A. Leskiw
Pedology Consultants
9120 - 37 Avenue
Edmonton, Alberta
T6E 5L4

David Lloyd
Land Management and Development
Alberta Forestry
4th Flr., S. Tower, 9915-198 St.
Edmonton, Alta. T5K 2C9

Sarah B. Lowe
Property Manager
TCG Materials Ltd.
P.O. Box 1390
Brantford, Ont. N3T 5T6

Phillip D. Lulman
Supervisor, Mining Reclamation
Transalta Utilities
1440 - 23 St. S.W.
Calgary, Alta. T3C 1H6

Angus MacLeod
B.C. Ministry of Forests
1011 Fourth Avenue
Prince George, B.C.
V2L 3H9

Harvey Martens
Reclamation Specialist
Hardy Associates (1978) Ltd.
221 - 18th St. S.E.
Calgary, Alta. T2E 6J5

Ann McGee
Faculty of Forestry
2357 Main Mall
Univ. of British Columbia
Vancouver, B.C. V6T 2A2

Frazer McKenzie
B.C. Research
3650 Wesbrook Mall
Vancouver, B.C.
V6S 2L2

Bruce McTavish
Nursery Operations
Reid, Collins Nurseries Ltd.
2396 - 272 St., P.O. Box 430
Aldergrove, B.C. V0X 1A0

R.E. Michelutti
Environmental Biologist
Falconbridge Ltd.
Falconbridge, Ontario
P0M 1S0

Dr. Patrick Miller
Landscape Architecture
2357 Main Mall
Univ. of British Columbia
Vancouver, B.C. V6T 2A2

F. Marlin Murphy
Senior Environmentalist
Gregg River Resources Ltd.
120 Maligne Place
Hinton, Alta. T0E 1B0

David R. Murray
Resources & Environment Section
Regional Development Branch
Agriculture Canada
Ottawa, Ont. K1A 0C5

Susan Norman
Soil Specialist
Box 408
Lions Bay, B.C.
V0N 2E0

Thomas Oddie
Monenco Ltd.
400 Monenco Place
801 - 6th Ave. S.W.
Calgary, Alta. T2P 3W3

Dirk Oostindie
Dist. of North Vancouver
P.O. Box 86218
North Vancouver, B.C.
V7L 4K1

Debra Pierson
Government of Canada
Fisheries and Oceans
1090 W. Pender St.
Vancouver, B.C. V6E 2P1

William T. Plass
Am. Soc. Surface Mining &
Reclamation
21 Grandview Drive
Princeton, W. Virginia 24740

David F. Polster
Polster Environmental Services
Box 152
Revelstoke, B.C.
V0E 2S0

Hugh Porter
Water Management Branch
Min. of the Environment
765 Broughton Street
Victoria, B.C. V8V 1X5

Ken Potter
Manager, Property Division
Burnco Rock Products Ltd.
812 - 46 Avenue, S.E.
Calgary, Alta. T2H 2P9

Leslie Powell
Government of Canada
Fisheries and Oceans
1090 W. Pender St.
Vancouver, B.C. V6E 2P1

Chris Powter
Research Manager
Research Management Division
Alberta Environment
Edmonton, Alta. T5J 3N4

Bill Price
Department of Soil Science
2357 Main Mall
Univ. of British Columbia
Vancouver, B.C. V6T 2A2

Holly Quan
Environmental Planner
Transalta Utilities
110 - 12 Avenue S.W.
Calgary, Alta. T2P 2M1

G. Paul Rideout
Gov. of Newfoundland and Labrador
Department of Environment
P.O. Box 4750
St. John's, Nfld. A1C 5T7

Dave Sahlstrom
Terrasol
P.O. Box 2092
Vancouver, B.C.
V6B 3T2

Mark Sahlstrom
Terrasol
P.O. Box 2092
Vancouver, B.C.
V6B 3T2

Robbie O. Scott
Environmental Technician
Eldorado Resources Ltd.
P.O. Box 2070
Saskatoon, Sask. S7K 3S7

Howard Slavinski
Land Reclamation
Alberta Environment
9820 - 106 Street
Edmonton, Alta.

Harro Starck
1527 Gordon Ave.
West Vancouver, B.C.
V7V 1T8

Sam Takyi
Reforestation & Reclamation
Alberta Forest Service
9920 - 108 St
Edmonton, Alta. T5K 2M4

Dr. Jack Thirgood
Professor, Fac. of Forestry
2357 Main Mall
Univ. of British Columbia
Vancouver, B.C. V6T 2A2

Dr. A.R. Thompson
Westwater Resources
2075 Westbrook Mall
Univ. of British Columbia
Vancouver, B.C.

Mark Walmsley
Principal
Pedology Consultants
1009 Langley Street
Victoria, B.C. V8W 1V7

Loren J. Winnick
Industrial Reclamation Co-ord.
Dept. of Forestry
17304 - 106 Street
Edmonton, Alta. T5X 3G8

Dr. Keith Winterhalder
Dept. of Biology
Laurentian University
Sudbury, Ontario
P3E 2C6

Ian Wright
110 Edinburgh Drive
Port Moody, B.C.
V3H 2T6

Paul Yeung
Soil Scientist
Alberta Environmental Centre
Bag 4000
Vegreville, Alta. T0B 4L0

Paul Ziemkiewicz
Reclamation Research
Alta Energy & Natural Resources
10909 Jasper Ave., 2nd Flr.
Edmonton, Alta. T5J 3M8

Elizabeth Zweck von Zweckenburg
Soils Agrologist
B.C. Agric. Land Commission
4940 Canada Way
Burnaby, B.C. V5G 4K6

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ORGANIZING COMMITTEE

B.C. Chapter CLRA
P.O. Box 2092, Vancouver, B.C.

Shannon Berch
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